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Original Articles

THE LATE GEORGE ARCHIBALD DOUGLAS STUART, I.C.S.

THE death of Mr. G. A. D. Stuart, I.C.S., Director of Agriculture, Madras, came as a severe blow to the Department which he has so ably directed during the last 5 years and to his many friends in India. Mr. Stuart, who was born on 1st December, 1879, was the son of Mr. G. H. Stuart, a former Director of Public Instruction, and the nephew of Sir Harold Stuart. He was educated at Weymouth School and Emmanuel College, Cambridge. He joined the Indian Civil Service in the year 1902, his first post being that of Assistant Collector of Pollachi Division in the Coimbatore District. Thereafter he was engaged in Settlement work in the Salem District and also in the districts of Chingleput and North Arcot. In 1911 he acted as Director of Agriculture for a short period, and received the permanent appointment in 1916, on the transfer of Mr. D. T. Chadwick to the post of Indian Trade Commissioner in London, which he held to the date of his death. To follow two Directors of the calibre of Mr. M. E. Couchman and Mr. D. T. Chadwick was no light task, but Mr. Stuart soon established himself in the confidence and affection of the members of his Department, and the pleasant relations which existed between them continued to the end. He officiated for Mr. Mackenna in the post of the Agricultural Adviser to the Government of India for six months in 1919. Mr. Stuart's popularity was not confined to Madras and he was a genuine favourite with all the members of the Department throughout India. He was one of the ablest and most popular members of the Board

of Agriculture where his practical commonsense combined with a genuine confidence in his Department earned him the respect of every one.

The affection and esteem in which Mr. Stuart was held by the members of the Madras Agricultural Department has been admirably summarized by one of them as follows :—" His sympathy for the Madras Agricultural Department was whole-hearted. He never promised if he saw no chance of performing. If he promised to help, he helped to the best of his ability and never spared himself. He never took credit that was due to another."

THE LATE GEORGE ARCHIBALD DOUGLAS STUART, I.C.S.,

SOME COMMON INDIAN BIRDS.

No. 13. THE INDIAN HOUSE-SPARROW (*PASSER DOMESTICUS INDICUS*).

BY

T. BAINBRIGGE FLETCHER, R.N., F.L.S., F.E.S., F.Z.S.,
Imperial Entomologist;

AND

C. M. INGLIS, M.B.O.U., F.E.S., F.Z.S.

THE Indian House-Sparrow needs little introduction to our readers, as it is only too familiar throughout India, occurring abundantly in all towns and by no means uncommonly in all country districts. The Indian race differs slightly from the form so familiar in Europe in being usually much whiter about the sides of the head and in having more black below the eye and at the base of the cheeks, so that the Eastern form looks more brightly coloured than the Western, but these characters vary considerably and the Indian race is not now considered as more than a local form of the European species. However, as Hume says, "What is in a name? Call him *domesticus* or *indicus,* it doesn't alter his depraved nature, does not make him one whit less detestable—only there is a certain *lucus a non lucendo* sarcasm involved in the Linnean name that aggravates.

"If domesticity consists in sitting upon the punkah-ropes all day, chit, chit, chit, chittering ceaselessly when a fellow wants to work, banging down in angry conflict with another wretch on to the table, upsetting the ink, and playing old Harry with

everything, strewing one's drawing-room daily with straw, feathers, rags, and every conceivable kind of rubbish in insane attempts to build a nest where no nest can be—if, I say, these and fifty similar atrocities constitute domesticity, heaven defend us from this greatly lauded virtue, and let us cease to preach to our sons the merits of *domestic* wives! Conceive a wife evincing similar tendencies! Why, there isn't a jury in the country who would not return a verdict of 'sarve her right,' even if the unhappy husband should have wrung her neck before the golden honeymoon had run out."

The above condemnation of the Sparrow is certainly sweeping but there is no doubt that this bird must be regarded as a decided pest of all well-ordered households in a country such as India, where the numerous open doors and windows afford easy entrance and exit and the lofty rooms and verandahs, with their heavy projecting cornices and numerous chinks and crevices, provide the Sparrow with such a convenient variety of suitable nesting-places. Noisy, pugnacious and untidy will perhaps sum up the character of this bird. Cunning, crafty, hardy, and well-nigh omnivorous, it has become a parasite of the human race and is well described by the epithet of "the avian rat," flourishing especially in localities, such as towns, where human activities have upset the normal balance of Nature and destroyed or driven away the natural checks, especially the birds of prey which help to reduce the numbers of this bird in rural areas.

In Europe, America and Australia the House-sparrow is justly regarded as a very serious pest of growing crops and, although relentless persecution is carried on and its numbers kept in check, it is still able to inflict annually loss and damage that can only be reckoned in millions of pounds. In India, things are not quite so bad mainly because the Sparrow is kept in check by natural causes except in large towns. Not only do its disorderly and noisy habits make it an active nuisance in and around houses, but its food consists largely of vegetable matter acquired at the expense of its rightful human owners. Mr. Mason examined the stomach-contents of eight birds at Pusa and Mr. d'Abreu of eight

others at Nagpur and in all cases they were found to contain seeds of various grasses, including cultivated forms such as rice and oats; none of the birds from Nagpur contained any insects and of the eight from Pusa only two contained, between them, two small weevils and another small beetle. The young nestlings, it is true, are fed largely on an insect diet, composed chiefly of caterpillars, but as the young grow older the proportion of insect food given them is diminished until, when they are about three weeks old, their diet is made up almost wholly of grain. The same story is revealed in Australia, whither this bird has been introduced with the unfortunate results so often encountered in the case of introduced animals and plants and in a Bulletin on "The Food of Australian Birds" we read that, of 127 Sparrows examined, sixty-four birds contained wheat and maize seeds and it is remarked that this bird is "a pest anywhere, in spite of the fact that it eats many insects." Besides grass-seeds and occasional insects, the Sparrow does not disdain the smaller fruits and in the mulberry season an extra annoyance is added to its presence in houses owing to its partiality for this fruit.

The nesting season is principally from February to May but two or more broods are undertaken annually and breeding continues throughout the year, the semi-domesticated conditions of this bird's existence not restricting it to any one season of the year. Its nest is a shapeless bundle of straw, grass, rags, wool or anything else obtainable, thickly lined with feathers and stuffed into any available hole or recess in or about houses, walls, old wells, etc., or rarely even in the centre of a thick bush. If a tree or a climber on a wall be chosen for the nesting site the nest is better made and is often a substantial dome-like structure with the entrance at the side, but its position is usually betrayed by long untidy pieces of straw left trailing outside. Five or six eggs, sometimes even more, are laid at each breeding season, the eggs being typically somewhat elongated ovals and but little pointed, either greenish, greyish, or yellowish-white, marked with close frecklings, fine lines or smudgy streaks of dull dingy sepia, olive, yellowish or purplish-brown, these markings being sometimes

sharply defined, and often showing a tendency to form a blotchy, mottled, ill-defined cap at the larger end. The eggs vary much in size but average about 20 mm. long by 15 mm. broad.

Besides the natural enemies of the older birds, the nestlings are attacked whilst in the nest by the grubs of a fly, *Passeromyia heterochæta*, which lays its eggs in the nest and whose larva buries its anterior extremity in the skin of the nestling, usually under the wings or the legs, and sucks its blood. This fly is widely distributed in Africa and has been found in China and in India at Pusa and Coonoor and is probably widely distributed in India. The numbers of the adult birds are largely kept down in the *mofussil* by hawks and probably also by the Indian Vampyre Bat (*Lyroderma lyra*) which hunts by night along the hedges in which these birds congregate in the evening to sleep in flocks, this habit affording an opportunity of netting them in quantity when it is desired to reduce their numbers.

The Indian House-sparrow occurs throughout the entire Indian Empire and in Ceylon but is not found in the Andamans or Nicobars or in the south of Burma. It ascends the Himalayas to moderate elevations. It is only too abundant in most parts of its range but is rare in some localities.

CO-OPERATIVE CONSOLIDATION OF HOLDINGS IN THE PUNJAB.

BY

H. CALVERT, I.C.S.,

Registrar, Co-operative Societies, Punjab.

THERE has been so much written about the evils and drawbacks of excessive fragmentation of holdings that the subject needs no introduction. In the Punjab the average holding is somewhere between six and fifteen acres ; the actual figure depends on whether holdings of less than one acre, and holdings attached to houses, etc., are omitted. This holding is sufficient to maintain a family in decent comfort if the right crops are grown, if the land is put to the best use, if adequate capital is invested and if several other conditions are fulfilled. But for these small holdings, it is essential that the fields should be concentrated in one place, so that the attention, the time, the energy and the intelligence of the cultivator may also be concentrated there. In this province, however, custom orders otherwise. The land is held by the owners of villages either by ancestral shares or by actual possession on the ground ; the tendency now-a-days is for an owner's rights to be measured by the actual area in his possession, plus a share in the village common, or *shamilat*. The universal custom is for sons to inherit equal shares, except where there are sons by different wives, when it sometimes happens that the sons of each wife inherit an equal share and divide amongst themselves. These shares may be held in common, the brothers arranging amongst themselves the fields each shall cultivate or even cultivating in common and sharing the produce. There is a strong

tendency, however, for each brother, especially when he begets a family, to take his own share as his separate property and to leave his brothers alone in the management of their own shares. There is no custom, such as is found in Europe where the Code Napoleon is in force, of the elder brother buying out the younger and so becoming sole proprietor of the ancestral land. The effect of these tendencies is for the land to be held in smaller and smaller parcels; and, as on partition amongst the heirs each claims and expects to get a share in each kind of land, each owner becomes possessed of a number of fields scattered throughout the area of the village. In those portions of the province where the crops were more secure owing to the rainfall being more assured, this fragmentation has proceeded to a greater extent than in districts with precarious rainfall, where a small scattered holding would not have sufficed to maintain a family. Perhaps, this tendency has gone further in Jullundur than in any other district. Jullundur is in the central Punjab; its fertility has led to the growth of a large population pressing heavily on the soil; the facility with which wells can be constructed has led to the land becoming largely dependent on this form of irrigation; the forces making for fragmentation have under these circumstances produced some startling results. In eight villages, the average field does not exceed one-fourth of an acre in area; the 2,549 owners possess 12,800 acres, or about five acres each, but these 12,800 acres are divided into no less than 63,492 fields, so that each owner has on the average 25 fields. In one village, 584 owners own 2,353 acres in 16,311 fields, the average being one-seventh of an acre. In the neighbouring districts of Hoshiarpur and Gurdaspur the process of fragmentation has resulted in similar conditions. In the rest of the province, outside the great canal colonies, somewhat similar features are to be found, though not to so marked an extent.

In Jullundur, owing to the successive partition of holdings, shares in wells have also been divided, so that a man may own a one-sixteenth of one well, and one-eighth of another and so on. The economic loss due to this system may be imagined.

The evils of fragmentation are obvious ; the remedy is not so easy to find. It so happens that the three districts mentioned are those in which co-operation has made most progress, and in which the co-operative spirit has been best developed. It occurred to me that a solution along co-operative lines might be found which would prove acceptable to the cultivators. To this end, I propounded a scheme and discussed it with co-operators and the staff at various meetings ; as a result model by-laws were prepared with an explanatory note, and efforts were made to persuade owners to give the scheme a trial. It was essential that the experiment should rest upon a voluntary basis, for the simple reason that there were no powers of compulsion ; at the same time it appeared necessary to insert a provision for decision by a majority in case one or more owners turned obstructionist. The scheme put forward was as follows :—Each owner had to agree to the desirability of consolidation, and to the general idea of repartition of the village lands with this end in view ; each such owner had then to agree to abide by any plan of repartition approved by two-thirds of all the owners ; and further to give up possession of his own lands and to accept in exchange the lands allotted to him ; all disputes to be referred to arbitration ; possession so given was to be cultivating possession for four years only, on the expiration of this period, the former possession was to be restored unless all the participating owners unanimously agreed to retain the new division as permanent ownership. Persons accepting these conditions could form a Co-operative Consolidation of Holdings Society. The general meeting would discuss the method of partition and decide on the main principles to be observed, such as the kinds of lands, the retention of former possession, and whether minor differences as to trees, etc., should be made good by money payments, and so on. In the case of any difference of opinion, any resolution would only be binding if two-thirds of the members approved of it. If there were not two-thirds of all the members in favour, then it would be necessary to devise some alternative method, or the society would dissolve. When a method of partition had been decided upon, the managing committee was to proceed to draw

up a scheme of repartition in accordance therewith. This scheme was to be placed before the general meeting ; if two-thirds of all the members accepted it, it would be binding on all, otherwise it was to be discarded. If a scheme received the approval prescribed, members were bound to give up and accept possession in accordance with it. A member, who felt aggrieved, could refer the point in dispute to arbitration. Members, thus exchanging land, would be tenants for four years ; during that period, any, who chose to convert this temporary possession into permanent exchange of ownership, were at liberty to do so ; and it was intended and hoped that many, if not most, would do this before the four years elapsed. At the end of four years, members would have to decide whether they would revert to the former possession or make the new scheme permanent or retain the temporary arrangement for a further period. Failing complete unanimity, the fields were to be restored to the former owners, and the society would automatically come to an end at the end of five years. The extra year was allowed for the settlement of disputes by arbitration.

Under this scheme, a member only bound himself for four years ; he agreed to abide by the decision of two-thirds of all the members as to the mode of partition, and by a similar majority as to the actual partition on the ground. He could not be deprived of his old fields beyond four years without his own consent, as an unanimous vote was necessary to convert the exchange into a change of ownership.

This was the scheme. In placing it before the people, the staff relied upon preaching and persuasion, and not upon the element of compulsion. The people soon came to see and appreciate the advantages, but everyone feared that he, at least, would lose by giving up his own very precious fields for someone else's inferior ones. It was obvious that if a revolution of this nature was to be carried through on a permanent basis, everyone must be satisfied and no one must be left discontented. It might be possible to repartition one or two villages by catching the hesitant over the compulsory clauses ; the general idea would fail if there were any disgruntled to decry it throughout the neighbourhood.

With such considerations in view, the power of compulsion by two-thirds majority has so far never been used ; if anyone objects to one plan another is tried and so on until everyone is satisfied ; in one case at least the staff were too anxious for results, and paid too little attention to objections with the consequence that the owners refused to have the decision ratified when it was placed before the Revenue Officer.

Now for the accomplishment. The staff of the Co-operative Department are for the most part sons of actual cultivators, and so in sympathy with rural feeling ; the inspectors are now generally graduates in economics who study practical applied rural economics in the ordinary course of their duties ; they exercise no legal powers at all ; they have to rely upon their powers of propaganda and persuasion ; they are specially educated men speaking to their brethren with knowledge begotten from careful training.

In all 69 Societies for the Consolidation of Holdings have been registered * ; each society has been organized in a different village, but it is not always the whole village that is put to repartition at once. Sometimes a block of land is tried as an experiment, sometimes a subdivision, sometimes the whole area.†

In 45 villages complete or partial repartition has been concluded, in 39 cases the repartition has been confirmed before the Revenue Officer (mutation has been sanctioned), and the change incorporated in the records ; in the remainder, mutation is pending until the officer visits the village. The gross result is that 1,653 owners, who formerly possessed 8,100 acres in 10,906 fields, now have this land consolidated into 2,071 fields.

The reduction in field numbers exaggerates the effect, as in many cases an owner had previously two or more fields contiguous ; but there can be no doubt that the scattered holdings have been changed for solid blocks. The average size of a field before consolidation was three-quarters of an acre ; now it is four acres. In eleven of these villages, before consolidation, the average size

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* Up to the end of September 1921.

† It is of special interest to note that, in several villages where only certain blocks were first readjusted, the owners of other blocks are now asking for help in readjustment.

of a field in each village was not more than half an acre ; now it is less than one acre in only one case, and less than two acres in two more.

In nearly all cases, the exchange of possession has been made permanent from the start. This was not advocated from the fear that a measure too revolutionary might not be found acceptable at first. As a matter of fact, when the owners have got so far as exchange of possession, the plunge into permanency is robbed of its terrors.

Of the economic results, it is too early yet to say much. Prosperity is not built up in a day ; but the reports received show already some changes. In one village it has been possible to get rid of a guard (*rakha*) over the crops, thus saving a sum equal to a considerable proportion of the revenue charged on the land. In Ghazikot rents have increased for the compact blocks, as the tenants find these more easy to manage. In this village the consolidation has created parcels of land which can be irrigated from a well ; previously fields were on the average three-quarters of an acre in area, now the average is over four acres ; the former is too small to justify a well, the latter is large enough to make one profitable ; already six new wells are under construction. Another advantage discovered is that, with larger fields, there is much economy of canal water. To irrigate a number of petty scattered fields involves a waste of water as it has to be carried over a number of channels ; with a consolidated holding this source of waste diminishes. In another village it is proposed to plant fruit trees on portions of the new parcels of land.

In some cases it has been found that the fields were actually too small to make cultivation worth the trouble involved, and were left untouched in consequence ; this difficulty has now disappeared. In one village the owners, after consolidation had given them compact parcels, bought Meston ploughs. These ploughs are not handy for the very small fields, but this difficulty does not remain when the fields are large.

Of difficulties much could be written. Every owner fancies his ancestral plots are the best and dislikes the idea of exchange ; old

men hate to be disturbed, minors require special consideration; the very small owners see no advantage, the bigger men have sometimes got more than they are entitled to and repartition would take this away; mortgagees oppose any alteration, and occupancy tenants fear that their rights will be lost if their possession is disturbed; some owners have migrated in search of work and their consent cannot be obtained. All these must be met and surmounted with patience and tact. Other difficulties are of a different order; the village patwari sees his income from disputes, from copies for court use, and from other little sources threatened with reduction; he also fears that with compact holdings the number of patwaris will be reduced and his conscience suggests that, if the worst men are dismissed, he will not be a survivor. The higher revenue authorities have shown much interest in the work, and as success is achieved, this interest should grow.

The most important feature about the work done is that it has been shown that consolidation can be carried out in actual practice; the stage of discussion and opinion and pious resolution has been left behind. A beginning has been made, a small beginning, perhaps, but still a beginning, which is better than none at all. The year's work marks a definite step forward.

The work demands the utmost sympathy and patience; nothing must be rushed, nothing left unexplained; every man's objection must be removed, even if he be the smallest owner in the society. A village well satisfied with its experiment in consolidation will be of more value for propaganda than many lectures. The cultivators readily grasp the advantages; each is ready to take his neighbour's land, but not so ready to give up his own. The main elements of co-operative action must be carefully preserved. The agreement to join in such a society must be voluntary and based upon the realization of a common need and of the desirability of securing it by common action. Within the society, everyone, be he a big owner or a small one, must have an equal voice; the smallest man may make the loudest complaints; the executive work must be entrusted to an

elected committee but this must be answerable to the general meeting; no one must seek advantage at the expense of his neighbour. The time for any element of compulsion from Government has not yet arrived; there must be a long period during which the measure gains in popularity and acquires the confidence of the majority; public opinion in its favour will grow as more and more instances of the practical advantages can be published abroad. Unless the unexpected happens, years of steady persistent propaganda will be required before the evil of fragmentation has been scotched.

We are not prepared to advocate any legislation at this stage; it is probable that several steps will prove necessary in succession. At present, there seems to be desirable some measure of protection of minors and their guardians, especially of the guardians; it may, for instance, be necessary to provide that an act of consolidation approved by a guardian and by the general meeting shall be presumed to have been done in good faith. Then it may be necessary to enact that mortgage deeds relating to specific parcels of land shall be deemed to apply to the land received in exchange on consolidation. Occupancy tenants, who lose their rights by abandonment or those who have no power to transfer their rights, may need protection, although it is hardly conceivable that any court would penalize a man for consolidation. Then there is the difficulty connected with absentees; in the central districts of the province, it is not uncommon for the poorer cultivators to seek their fortune in America or Australia, etc., without abandoning their rights in their ancestral plots. At present the brother usually guarantees the consent of the absentee, but there are dangers in this. Tenants who claim compensation for disturbance may give trouble, but this should not be beyond adjustment. The time for compulsion has not yet come, but the experience of other countries suggests that without some such power the work will not proceed very far. Hitherto, the propaganda has been carried on amongst co-operators whose experience of the credit society has served to show the advantage of joint

association, and it will be better to let the successful examples speak for the merits of the scheme before any compulsion is contemplated.

The work is proceeding steadily, and it is hoped that about 100 to 150 more villages will be readjusted during the current year.

Statement showing work of consolidation done in 1920-21.

Serial No.	Name of society	No. of members	Area consolidated in Kanals	Previous No. of fields	Present No. of fields	Average area per field in Kanals: Before consolidation	Average area per field in Kanals: After consolidation	Remarks
1	Nowshehra ..	12	1,196	147	21	8	57	Mutations are said to have been sanctioned.
2	Bahadur ..	18	1,112	265	38	4	29	
3	Ghazi Kot ..	10	7,965	1,139	240	6	33	
4	Bhabra ..	24	2,381	479	136	5	18	
5	Jagawal ..	10	994	149	38	7	26	
6	Niamatpur ..	10	660	117	9	6	74	
7	Manoharpur ..	11	1,034	165	7	6	148	
8	Makhanpur ..	10	867	121	17	7	51	
9	Sheikh Kabir ..	16	900	155	46	6	20	
10	Kotla ..	22	470	150	42	3	11	
11	Chak Nooroowala	22	770	140	55	5	14	
12	Bucha Nangal ..	22	1,000	250	58	4	17	
13	Lakhan Kalan ..	11	1,100	155	38	7	29	
14	Gagraoyian ..	10	2,400	350	60	7	40	
15	Nath ..	18	897	96	29	9	31	Mutations not attested yet.
16	Chak Mubarik ..	12	840	81	24	10	35	
17	Bhochra ..	11	3,200	500	164	26	78	Mutations sanctioned.
18	Khurpa ..	21	992	83	16	12	62	
19	Momanpur ..	21	757–18	127	21	6	36	
20	Ghazipur ..	92	2,586–18	825	102	3	25	
	TOTAL ..	383	32,122–16	5,494	1,161	..	..	Carried over

Statement showing work of consolidation done in 1920-21—contd.

Serial No.	Name of society	No. of members	Area consolidated in Kanals	Previous No. of fields	Present No. of fields	Average area per field in Kanals		Remarks
						Before consolidation	After consolidation	
	Brought forward ..	383	32,122–16	5,494	1,161			
21	Bhetthe ..	26	951– 7	174	58	5	17	
22	Alamgir ..	87	2,423– 5	583	59	4	41	
23	Bajra ..	67	827– 8	305	27	3	31	
24	Kahlwan Patti Ram Singh ..	10	727– 6	76	12	10	61	
25	Chotala ..	78	1,363– 3	169	35	8	39	
26	Safdarpur Patti Gujran ..	12	657–14	38	5	17	132	
27	Tur ..	22	349–12	49	15	7	23	Mutations sanctioned.
28	Noshera ..	12	1 312– 9	23	19	57	69	
29	Dhido Kutrala ..	13	702– 2	177	105	4	7	
30	Rajpur ..	11	487– 4	60	14	8	35	
31	Behrampur Patti Bhathian ..	53	2,742–13	200	54	14	51	
32	Behrampur Patti Jailewala ..	75	4,793– 9	255	39	19	123	
33	Saila Khurd ..	73	301–15	116	24	3	13	
34	Badhel ..	17	429– 0	88	8	5	54	
35	Semi ..	45	2,221– 9	703	38	3	60	Mutations pending.
36	Garhshankar Patti Jaora ..	16	1,456– 0	386	16	4	91	
37	Ida ..	88	1,185–15	124	48	10	25	
38	Mohmohial Yusufpur ..	45	1,456– 9	90	20	16	73	Mutations sanctioned.
39	Bir Udhowal Patti Jhangian ..	101	1,292– 2	194	55	7	24	
	TOTAL ..	1,234	57,802–18	9,304	1,812	..	..	Carried over

Statement showing work of consolidation done in 1920-21—concld.

Serial No.	Name of society	No. of members	Area consolidated in Kanals	Previous No. of fields	Present No. of fields	Average area per field in Kanals: Before consolidation	Average area per field in Kanals: After consolidation	Remarks
	Brought forward	1,234	57,802–18	9,304	1,812			
40	Dhaliwal Patti Mana ..	181	2,041– 6	679	102	3	20	Mutations sanctioned.
41	Sargondhi Patti Jattan ..	25	903–19	182	19	5	48	Mutations sanctioned.
42	Dhanipind Patti Gil ..	57	446– 2	117	25	4	18	Mutations sanctioned.
43	Zainpura ..	99	2,017– 0	160	42	12	48	Mutations sanctioned.
44	Ball Hukmi ..	17	1,500– 0	341	44	4	34	Mutations pending.
45	Goraya Patti Manga ..	40	289	123	27	2½	11	Mutations pending.
	TOTAL ..	1,653	65,000– 5	10,906	2,071	6	31	

COW PROTECTION.*

BY

W. SMITH,

Imperial Dairy Expert.

A GREAT deal has been said and written on this subject in India, and vast sums of money donated by pious Hindus are spent yearly on the maintenance of Pinjrapoles, Gowsalas, and various organizations in order to prevent the slaughter of cows, and to ameliorate the lot of aged and suffering cattle. The cow is held in veneration by the Hindu community, and the whole of the people of India, whether Hindu, Mahomedan, Sikh or Christian, look to her for part of their food-supply in the form of milk, *ghi* (clarified butter), or other milk products. The great mass of Indians are vegetarian, and there is nothing which can take the place of milk and the milk fats in their dietary. Recent investigations have proved that the vegetable oils which are offered as butter fat substitutes are lacking in what is known as vitamines, which are essential to the growth and the general well-being of the body. Most Indians do not eat animal fats and, consequently for the fatty part of their daily ration rich in the necessary vitamine principle, they must rely on butter fat alone.

In view of these facts, it seems that, even from a purely utilitarian point of view, it is good to have a very special regard for the cow and all which pertains to her well-being, and consequently cow protection is a necessary plank in the economic platform of Indian progress.

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* Note sent, on request, to the Principal Director of the Goraksha Mundal, Ltd., Calcutta.

Some prominent men in India advocate prohibition of the export of cattle as a form of cow protection, others call for Government orders prohibiting the slaughter of cattle for food, while a section of the rural community consider that the setting apart by the State of large areas of land for grazing purposes only would solve the problem. No doubt something can be said in favour of all these proposals, but it seems to me that the first and most needful form of cow protection urgently wanted in India is the stoppage of the slaughter of young cows and female buffaloes in the large cities.

In Calcutta and Bombay, and to some extent also in other large cities, practically the total fresh milk supply of the city is produced from cows fed, housed, and milked right within the city limits. These cattle are purchased in the prime of life, and generally with their second calf at heel, they are milked for one lactation period only, say, 9 months, and then immediately slaughtered to make room for another cow just calved, which of course shares the same fate as her predecessor, and so the pernicious system goes on.

Up to sixty years ago, when railways began to serve as transport arteries to and from the great cities of the world, this system, which may be called the "cow-feeding" system, was in vogue in all the great cities of the world, and up to 1864 the whole of the milk consumed in the city of London was produced by "cow-feeders" in or near the city. An outbreak of rinderpest amongst the London cows brought home to the late Sir Geo. Barham, then a London cow-owner, that milk could be purchased at farms in the country, railed into London, and sold there, of better quality, cleaner, and cheaper than the city produced milk. He at once put the idea into practice and made a fortune in so doing, because the production of milk in a large city from cows tied up all the year is not only insanitary and unnatural, but it is uneconomical, and from the point of view of cost it cannot compete with milk produced on the land by a *bonâ fide* farmer who keeps his cows over the dry period and only disposes of them when they have become inefficient through old age, sickness, or accident.

The experience of the city of London has been the experience of practically every large city in the civilized world with the exception of Calcutta and Bombay. The introduction of milk from the country very soon ruined the cow-feeders of Paris, Copenhagen, New York, and Chicago, and to-day no cows are kept in these cities.

It may be asked why have economic conditions not asserted themselves in the Indian capital cities and driven out the cow-feeder as they have done elsewhere. The reasons are many. Firstly, there is a prejudice amongst Indian consumers against pasteurized milk, and of course in a climate like India milk cannot be sent from the country into the city unless it has been pasteurized and cooled. Secondly, the dairy industry in India has not been taken up by the trained business capitalist, but is carried on by poor men, uneducated and generally without organizing ability; and, thirdly, these men who work the milk trade in India have not the requisite technical knowledge to know how to treat milk intended for consumption some distance from the source of production, nor for that matter is there any school or college in the country where they can acquire such knowledge. India is the only civilized country in the world to-day which has no properly equipped dairy school or college. An attempt at teaching dairying has been made at some of the agricultural colleges, but only as part of a general agricultural curriculum, and it is within the last few months that the first professor of dairying has been appointed in India.

Within the last fifteen years, the export to foreign countries of cows or female buffaloes from India has not exceeded 1,000 head per year (not including the cattle sent by the Military Department to Mesopotamia to supply milk to war hospitals during the war), and within that same period of 15 years it may be taken that the cow-feeding system of milk production in our four largest cities has caused the slaughter of not less than 250,000 young cows and female buffaloes. Cattle-breeding in India is not in a highly organized condition and the country cannot stand this drain. How can it be stopped? No legislative measures are needed, but the

milk supply of our large cities must be organized on business lines and the milk produced under healthy conditions on the land where the cows will spend the whole of their natural lives. This milk must be pasteurized, cooled, and transported to the cities and sold there in proper sanitary packages by properly organized business units.

A city milk supply produced under this cow-feeding system cannot be a satisfactory one. The crowded lanes and back alleys of a great city not only militate against the production of clean milk of good quality, but it requires little argument to show that milk produced by cattle housed in the heart of a great city where land is worth rupees per square foot, where taxes are high and where the cost of labour, feed and water is a hundred per cent. over rural areas, must be expensive. It is very expensive, and therein lies the solution of both problems, *i.e.*, the untimely slaughter of young cows and the poor and expensive milk supply of our large cities. If public-spirited business men in India can be induced to take up the question of dairy farming and produce milk under natural conditions in suitable rural areas and offer such milk to the public in the large cities, they will be able to sell at such a price as the city cow-feeder cannot compete with and in a very short time drive this cow-feeding business out of existence, as has already been done in the other large cities of the world.

The milk supply of Calcutta and Bombay is not only the worst in existence, but it is the most expensive, and as an adequate supply of clean pure milk is an absolute necessity for the health of the community, the introduction of dairy farming methods and the transportation and sale of rurally produced milk in these cities not only is the best means of "cow protection" but, what is even more important, it is a sound method of "man protection" and will have a real effect on the health of generations to come.

The Calcutta Pinjrapole Society, it has been stated, spends some Rs. 1,50,000 per annum in prolonging, for a short period, the life of, say, a couple of thousand cattle, many of which have already

nearly reached the end of their natural existence. If the Indian merchants who support this society would put ten years' subscriptions into a soundly organized and properly equipped dairy farm, they not only would prevent the slaughter of, say, 2,000 young cows annually, but they would provide the citizens of Calcutta with cheap, clean, and pure milk, and at the same time earn for themselves a handsome dividend on their money.

WATER HYACINTH.

A SERIOUS PEST IN BENGAL.

BY

KENNETH McLEAN, B.Sc.,

Offg. Fibre Expert to the Government of Bengal.

Water Hyacinth (*Eichornia crassipes*) is a native of Brazil and has now acclimatized itself throughout the Tropics. It is killed by severe frosts, hence the more temperate zones are free from the pest. The genus is called after a German Minister who lived at the end of the 18th century, so that it is probable that the plant first became known about that time. It would appear that its spread has been due to its beautiful flower and that it found its way into the gardens in different countries, to spread eventually all over the countryside.

In Florida, "admirers of the plant placed plants in the St. John's River in front of their houses to beautify the surroundings."

Water hyacinth first came to be seriously considered as a pest in Florida in 1890, in Queensland in 1895, in Cochin China in 1908, in Burma about 1913, and in Bengal in 1914. Its profusion in Eastern Bengal at the time of the outbreak of war was credited, in some districts, to the Germans, and it became known in localities as the "German Pana."

The plant is supposed to have been introduced into Eastern Bengal in 1910, but there is evidence that the plant had been growing in Eastern Bengal for many years prior to that date. Khan Bahadur Moulvi Hemayetuddin Ahmad of Barisal talks of having seen it in the *bhil* (swampy) tracts of Backergunge in his boyhood, and

Mr. A. L. Godden states that it is on record that the steamer conveying Sir John Woodburn through the *bhil* route in 1898 or 1899 was delayed whilst the weed was cleared away.

The Narayanganj Chamber of Commerce was instrumental in bringing the danger of the pest to the notice of Government in 1914.

In August 1917, there were very high floods throughout Eastern Bengal and these, apparently, were the means of carrying away much of the weeds to the sea, as in 1918 and 1919 the progress of the pest seemed to have a set-back. In 1920, however, and in the present year (1921), water hyacinth has spread very rapidly, and serious complaints have been received of its stopping navigation and destroying the deep-water paddy crops.

In districts where *khals* (water-channels) are the only means of travel, serious difficulties have arisen both through delays and the enhancement of rates by boatmen (Plate II). Several rivers are reported to have become impassable due to the weed, notably the Bhairab in the Nadia District and the Gorai which flows between Faridpur and Jessore Districts. Rivers with slow flowing currents are quickly blocked with the weed.

Life-history of water hyacinth.

The following description of water hyacinth will be found in the Pusa Bulletin No. 71—"Water Hyacinth: its value as a Fertilizer"—by Messrs. Finlow and McLean. The authors were indebted to Mr. H. G. Carter of the Botanical Survey for the description.

"*Eichornia crassipes*, Solms., belonging to the family ontederaceæ, is a native of South America but has now become a troublesome weed in other countries, notably Florida, Java, Australia and India. The plant is a herb which multiplies extensively by division of the root stock.

"When floating in water the plant has large bladder-like leaf-stalks which make it remarkably buoyant. The blade of the leaf acts as a sail, so that the plant, which multiplies very rapidly, is carried about on the surface of the water and soon becomes a pest.

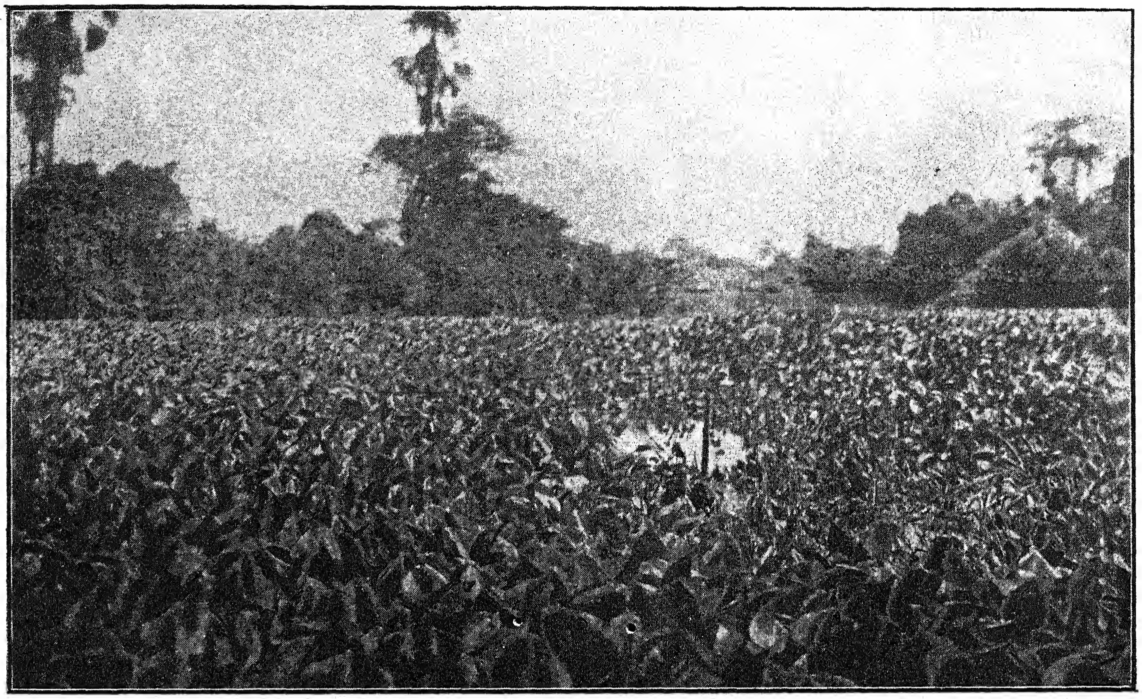


Fig. 1. *Khal* choked with water hyacinth.

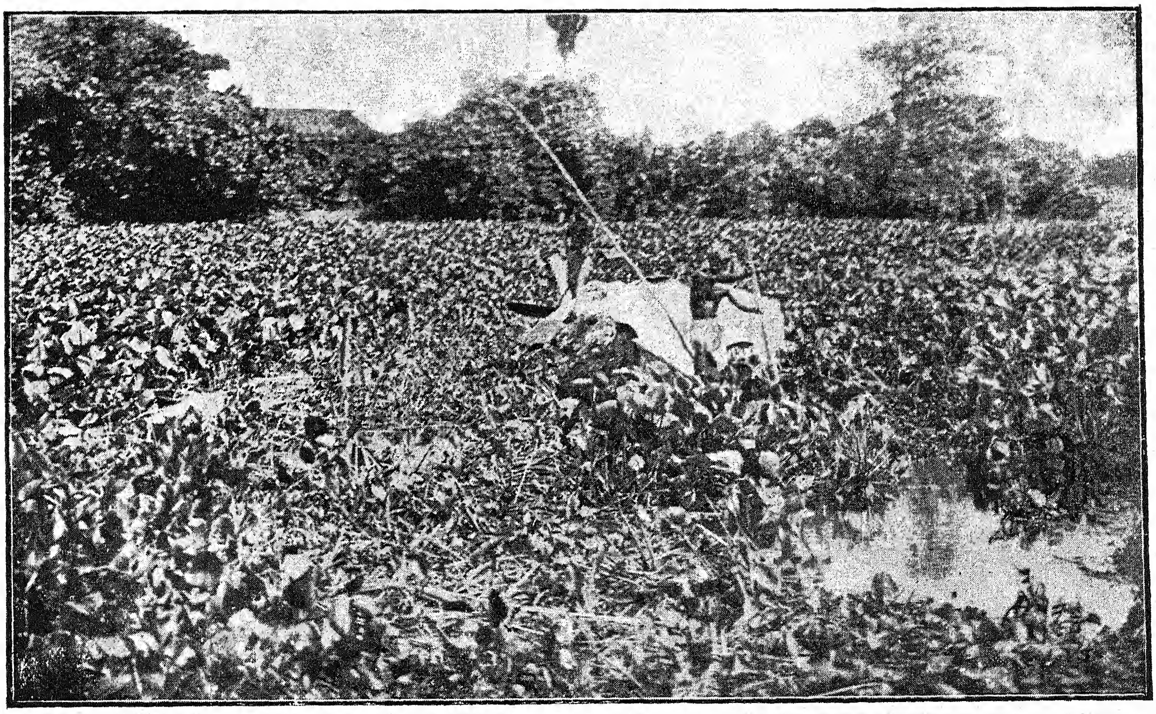


Fig. 2. Navigating a load of jute through hyacinth.

When growing in mud the bladder-like expansion of the leaf-stalk is absent. The plants bear spikes of ten or twelve handsome lilac flowers. The perianth is funnel-shaped and usually slightly irregular; it ends in six lobes. The six stamens are inserted on the perianth. The ovary is superior and three-celled and has axile placentation. The fruit is a loculicidal capsule containing seeds with abundant mealy endosperm."

In the "Standard Cyclopedia of Horticulture" Wm. Tricker writes:—

"This genus includes the water hyacinth, the famous 'million dollar weed' that obstructs navigation in the St. John's River, Florida, and is a source of wonder and delight in every collection of tender aquatics in the North."............"About flowering time the plant sends down anchoring roots which, if the water be only 3 or 4 inches deep, penetrate the soil."................"The common water hyacinth sends out two kinds of roots, the horizontal ones often thick and fleshy, and apparently for reproductive purposes, the vertical ones long, slender and clothed with innumerable small horizontal fibres..........."

The so-called horizontal roots should more properly be called "runners," special branches sent out for vegetative reproduction.

In neither of these descriptions is any reference made to the size of the plant, but in Bengal it has been found to attain a height of over 3 feet under favourable conditions.

It will be seen from the above descriptions that the plant in its own habitat is capable of reproducing itself both by seed and vegetatively. As regards propagation from seed, the following is taken from "Instructions for the eradication of the Water Hyacinth" issued by the Government of Burma in 1915:—"When the flowers fade, the stem bends over in the middle immersing the seed pods in the water; the pods opening, the seed escapes, seedlings form and in a few months themselves flower and send out runners."

No authority is quoted for this statement, but all attempts to germinate seed collected in Bengal have proved futile. Moreover, it was found that the number of flowers containing seed was small, only 1 per cent., and from a spike only one or two seeds were

obtained. The seed was tested for germination: (1) on dampened blotting paper, (2) in water, (3) in mud, and (4) in damp soil. The tests were made in February and the seed kept under observation for one month. The tests were made both under ordinary atmospheric conditions and in the incubator at a temperature of 86° F.

During the potash extraction experiments at Narayanganj in 1918-19 many thousands of the young plants were examined, but in every case showed evidence of having been detached from a parent plant.

The seed procured in Bengal appears to be perfectly formed and healthy. It may be noted that no seed could be found from plants growing in the red soil area.

The normal propagation in Bengal is by stolons or runners. These branch out from six to eight inches from the parent plant, forming on the end a rosette of small leaves. Roots spring out from the node where the rosette is formed and the young plant becomes self-supporting, and if the runner is broken floats away to continue propagation in another area. Those plants which continue attached to the parent plant also send out runners with the result that a matted mass surrounds the parent plant and individual plants are difficult to separate out. Water hyacinth is a perennial, and the death of the parent plant appears to be due to its being overgrown and submerged by its progeny.

In Circular No. 7 of 1919 of the Commonwealth of Australia it is stated that "the rate at which it grows has been a matter of careful observation, and a single root has in a few months covered a space of 600 sq. metres."

Mr. McSweeny, in conversation, stated that he had observed the growth from a single plant to cover 30 sq. yards in a few months in Assam. At Narayanganj, a tank from which the hyacinth had been taken out for the potash plant was found to be covered again with young growth in six weeks. In this case, however, no attempt had been made to clean the tank completely.

The bladder-like expansions of the leaf-stalk and the sail-like leaves are important assets to the plant in propagation. The former

enable it to float and the latter with the wind enable it to travel into new areas. This ability to travel is of very great importance in the spread of the pest and accounts for its spreading up-stream. In May of the present year the writer had an opportunity of seeing large masses of hyacinth being blown by the south wind up the Turag river. The writer and several independent witnesses estimated the rate at 3 miles an hour.

Operations against water hyacinth in Bengal.

The first steps regarding the spread of water hyacinth in Bengal were taken by the Agricultural Department as the result of a deputation from the Narayanganj Chamber of Commerce which waited upon H. E. Lord Carmichael and impressed upon him the danger to the waterways. Since this date, in 1914, the problem of combating the progress of the weed has been under the consideration, not only of the Agricultural Department, but also of District Boards and District Officers in different parts of the province.

The work of the Agricultural Department has been mainly concerned in finding out ways of utilizing the weed, whilst on the administrative side the problem has been the clearing and collection of hyacinth.

Utilization as manure. The Agricultural Department commenced an investigation into the possibilities of utilizing water hyacinth in 1914. The dried plant was found to be rich in potash and experiments were undertaken to arrive at the manurial value of both the rotted plant and the ash of the plant. With this object in view an extensive series of plots were laid down on the Dacca farm. The conclusions arrived at were published in the Pusa Bulletin No. 71 of 1917. These were, briefly, that the rotted plant is a valuable general manure slightly higher in value than cow-dung, and that the ash is several times richer in potash than wood ashes and therefore a valuable potassic manure. On the strength of these results cultivators were informed, through the agency of pamphlets and leaflets issued at different times, of the value of both the rotted hyacinth and the ash as manure.

This propaganda has had considerable effect as both the rotted hyacinth and the ash are used throughout Eastern Bengal as manure. There is, however, no doubt that the amount of hyacinth utilized in this way has had little effect in the reduction of the pest, as the cultivators take insufficient care in destroying the plants.

Extraction of potassium chloride. The high percentage of potash in the ash of the plant led the Fibre Expert to experiment on the possibilities of extracting potassium chloride. Prior to the war potassium salts had their chief source in the enemy countries, and on the outbreak of war prices soared high. Messrs. Shaw Wallace and Co. offered good prices for hyacinth ash, provided it came up to required standards as regards potash content, and arranged with middlemen for supplies. It was found that the ash arrived in such an adulterated condition as to make the extraction of the salt unprofitable and the firm lost money over the transaction. If the middlemen had played the game there would have been a large source of income, as the supply of potash salts both for munitions purposes and agricultural purposes was causing considerable concern to the Allies.

The process of extracting potassium chloride from the ash being a simple one, the Fibre Expert erected a small experimental plant at Narayanganj for the extraction of the salt. Mr. Basu, First Assistant to the Fibre Expert, describes this plant in the "Agricultural Year Book of the Department of Agriculture, Bengal, 1919." As a commercial adventure this plant proved unsuccessful but it was conducted under conditions which were adverse to success. Circumstances necessitated that labour had to be employed in collecting the hyacinth from tanks, carting it to the site of the extracting plant some considerable distance, drying it and burning it. In Narayanganj, moreover, labour is exceptionally expensive. A plant of this sort, situated in the vicinity of piles of the weed deposited by the elevator or grappler as in America, would probably show much better financial returns.

In 1920, the Collector of Dacca instituted a campaign against water hyacinth through the medium of the Panchayet Presidents,

introducing a "Hyacinth Day." In many Unions the work was taken up with a will, but the lack of enthusiasm on the part of neighbouring Unions disheartened the enthusiasts, whose land is again infected.

At a Panchayeti Conference held at Dacca on the 28th February, 1921, the effect of the order of the Collector was discussed and the opinions of the members who, as the Collector remarks, "have intimate experience of the evils of *kachuri* and of the possible ways of meeting these difficulties," are of great interest. The concensus of opinion of the meeting was that penalties should be imposed upon defaulters.

Failure to comply with the orders will always occur where no penalties are attached to non-compliance. In 1918 the Government of Bengal circularised all Commissioners and all public bodies including railway companies as to the necessity of taking steps to eradicate water hyacinth. A letter from the Agent, Bengal-Nagpur Railway, dated 12th December, 1919, is illuminating. He writes: "The whole of our borrow-pits between Howrah and Kharagpur and on other sections of the line outside Bengal were cleared this year at very considerable cost. It is now reported that practically nothing has been done by owners outside railway boundaries with the result that the borrow-pits on railway land have become re-infected and the work will have to be done again." The Agent of the E. B. Railway wrote in the same strain.

At a meeting of the Legislative Council, Bengal, a resolution was passed recommending to Government the appointment of a Committee "composed of official and non-official members under some scientific experts, such as Sir J. C. Bose or Sir P. C. Ray, to devise ways and means for removing the scourge of the water hyacinth and to combat it successfully, before any legislative action is taken, as recommended by the District Boards' Conference." In pursuance of the above resolution the present Committee under Sir J. C. Bose was appointed "to enquire into the spread of the water hyacinth in Bengal and to suggest measures for its eradication."

Operations against water hyacinth in other countries.

In the United States of America.

In the U. S. A. the plant first came to notice in the State of Louisiana in 1884 and in Florida in 1890. An interesting account, to which the writer is indebted for the following notes, will be found in "Lumbering and Woodworking Industries in the United States and Canada, Vol. III," by F. A. Leete, Indian Forest Service.

The Board of Engineer Officers constituted in 1897 to investigate water hyacinth recommended that systematic operations should be undertaken to keep waterways open for navigation. Operations on a large scale commenced in 1899 in both States. They began in each State on similar lines but subsequently developed on different lines, cattle owners in Florida instituting laws to prohibit the use of chemicals injurious to cattle.

Towing masses of the weed to sea. As the plant dies in salt water, drifting and towing the plant to the sea was first tried. Drifting to the sea was found to be the cheapest method of getting rid of the weed, but it is only possible where there is sufficient current. Surrounding masses of the weed with nets and towing them to the sea with a tow boat was found to be possible, but there was a leakage of plants *en route*, and this difficulty could not be surmounted and it was decided that towing would not be successful.

The erection of booms to confine the plant to restricted areas and to prevent it entering into back waters and channels which were required for navigation was found to be successful and is still a method in use. It has been found, however, that they are insufficient and attention has to be paid to the clearance of stray plants which find their way inside the channels.

Crushing the plant between rollers. Another method of destruction suggested by the Board of Engineers was the crushing of the plant between rollers mounted on a suitable vessel. The idea was given up as impracticable.

Solutions or mixtures fatal to the plant. An exhaustive series of experiments on the effects of spraying the plants with chemicals was commenced in 1906. The objects of the experiments were to find :—

(1) A solution or mixture fatal to the plant.
(2) Whether cattle would eat the plants with fatal effects after spraying.
(3) Whether anything could be added to make the sprayed plant obnoxious to cattle.

Of 23 different substances tried, only six were found to be effective in killing the plant. All six were found to be injurious to cattle. These six substances were :—

1. Fowler's Solution.
2. Sulphate of Copper.
3. Bi-carbonate of Potassium.
4. London Purple.
5. Arsenite of Lime.
6. Arsenite of Soda.

The first three were found to be too costly and the choice narrowed itself down to the arsenical compounds owing to their cheapness.

No substance could be found which would prevent the cattle from eating the plant.

Spraying water hyacinth in Louisiana. As noted above, spraying with chemicals is prohibited in Florida on account of the danger to stock but in Louisiana spraying is carried out on an extensive scale and is looked upon as a permanency. With three boats the District Engineer is just about able to keep pace with the growth of the plant. Complete eradication is considered impossible. Water hyacinth is found all over the State and much of the time of the boats is taken up in travelling backwards and forwards. The three boats used in the operations are the "Hyacinth," a stern wheeler specially built for the purpose, a Government barge, the "Chene," and a hired barge similar to the "Chene." The "Hyacinth" cost Rs. 1,20,000, but the cost of the other boats is not known. The "Hyacinth" carries tanks of

a capacity of 3,366 gallons and is fitted with a power sprayer capable of reaching 40 feet on each side of the boat, clearing a track of 80 feet. The area sprayed per day depends on how closely the hyacinth is packed, varying from 3½ to 10 miles by 80 feet.

The chemicals used are white arsenic (arsenious oxide) and soda (sodium carbonate). The usual strength is 1 in 10. On warm sunshiny days one gallon of the solution will destroy 10 square yards of closely packed hyacinth. On cloudy or cool days a larger quantity or stronger solution is necessary.

The recurring expenditure on spraying for 1917 is taken as Rs. 48,000, and the three boats sprayed an area of 5,021 acres. This works at a cost of Rs. 9-9 per acre, but in the statement given capital cost is not taken into account. Mr. Leete states that the cost per acre for the "Hyacinth" is Rs. 24.

Piling the hyacinth in heaps on the banks of rivers in Florida. Spraying being prohibited in Florida, mechanical piling has occupied the attention of the authorities in that State. In 1909 piling by means of an elevator was started and has been continued up to date. In 1916 a simpler contrivance called the "grappler" was tried and found very successful. The general idea of these contrivances is to lift the hyacinth out of the water and convey it to the bank of the river or channel where it is piled in heaps and allowed to rot.

Both the elevator and grappler are mounted on barges which are stationed near the bank, and the masses of hyacinth have to be dragged down to the site by means of ropes worked on windlasses. In the case of the elevator the plants are fed on to the foot of the elevator by men with rakes and they are carried by the elevator to the pile on the bank. The grappler works on a jib. It is dipped into the mass of hyacinth and, as it is raised by the engineer, mechanically grips a load of the plants. The jib is swung over to the bank where a man steers the grappler to the pile where the hyacinth is deposited.

The cost of clearing the hyacinth with the elevator is stated to be Rs. 33 per acre. No figures are given for the grappler which is still under experiment.

In Burma.

Construction of booms to collect hyacinth. In Burma instructions for the eradication of water hyacinth were first issued in January 1914 and revised instructions were issued in 1915. The instructions are confined to the erection of booms across the rivers and channels to catch the plants as they float down. The villagers are made responsible for the work, both for clearing the hyacinth from the banks above the booms and for dragging the masses of plants collected at the booms to the banks and burning them. Headmen of villages are empowered under the Burma Village Act (1907) to call out all able-bodied men, women, and children over the age of twelve to clear the hyacinth in their village tracts. Seemingly, the powers at the disposal of the authorities were insufficient, for in 1917 the Burma Water Hyacinth Act was introduced.

In Cochin China.

Construction of booms. It would appear that even before 1908 the prevalence of water hyacinth in the waterways was occupying the attention of the authorities in Cochin China, for Administrative Circular of Cochin China No. 12, 19th March, 1908, refers to previous orders on the subject. The order provides for the construction of booms to prevent the hyacinth from spreading into waterways not yet infected and for catching the masses of floating weed in the infected waterways so that they may be taken out of the water and piled on the banks. The plants must be heaped not less than 10 feet above high water-mark and, when sufficiently dry, burnt. With this object, during the first three days of each month or more often, if necessary, proprietors, farmers, and small holders must ensure the removal and destruction of plants within their holdings. The application of the order seems to have raised objections from some Administrators as in his Circular No. 29 of 27th January, 1911, the Lieutenant-Governor

sets these objections aside and insists on more strenuous measures, and mentions the appointment of river overseers to organize the destruction of water hyacinth.

In his Circular No. 147 of 26th June, 1911, the Lieutenant-Governor remarks on the success of the 500 embankments already established and proposes the extension of the scheme. From his concluding remarks it would appear that the obligations placed upon proprietors to destroy hyacinth on their land had been withdrawn.

In Australia.

Dredging in still water and floating to the sea in currents. Water hyacinth was known in New South Wales as early as 1895, and mention is made of 7½ acres of the weed in the Wollondry Lagoon having to be cleared at a cost of £8 (Rs. 120) in 1900. Mechanical collection of the weed with an outfit somewhat similar to the elevator used in America was found successful in the Bremer river. As in America the masses of weeds were towed up to the outfit. After the clearing, stray weeds along the banks were cleared up by men working from flat-bottomed boats. Where tidal currents prevailed the hyacinth was allowed to float down with the out-going tide and prevented from returning by the erection of booms at the turn of the tide. These operations have met with success in the two rivers, the Bremer and the Brisbane, where they were put into effect. Mr. E. A. Cullen, the Engineer for Harbours and Rivers, Brisbane, reports : "The rivers named at one time were covered almost entirely for 30 miles, so that motor boats could not pass, and steam lighter traffic was almost stopped. By the means adopted, *i. e.*, dredging the weed out in the relatively still water areas and drifting it down to salt water where tidal currents prevailed, the rivers are entirely cleared. An annual inspection and clean up of any few small patches occurring has kept the waters clean for several years at a cost of under £50 per annum."

Mechanical collection of the hyacinth and the manufacture of potash from the collected heaps is under contemplation in other parts of Australia.

Legislation against proprietors and tenants who fail to destroy water hyacinth growing on their land or adjacent waterways.

Legislation in Cochin China.

Attempts were first made in French Cochin China to legislate against people failing to destroy water hyacinth in 1908. The law then introduced not only required that all hyacinth should be destroyed, but also made landlords and tenants responsible for the construction and maintenance of barriers across the waterways for collecting weed floating down-stream. The law further stipulated that the work of clearing should be done during the first three days of every month. In the event of a proprietor failing to carry out his obligations, the district officers were empowered to do the work for him. The penalties of non-observance of the law are, unfortunately, not intelligible.

Provision is made in the orders empowering Chief Administrators to relax the law in certain cases and, as the Lieutenant-Governor mentions that objections were raised by his Administrators and in a subsequent circular mentions the withdrawal of the obligations placed upon proprietors, it appears that the Act was difficult to apply. The Director of the Scientific Institute, Saigon, in 1921 remarks that "the regulations issued in 1908 have not been applied with sufficient rigour to enable an estimate of their efficiency to be arrived at."

The Burma Water Hyacinth Act, 1917.

In 1917 the Burma Water Hyacinth Act was introduced. In this Act the presence of the water hyacinth is declared to be a public nuisance in Burma, and any person who possesses or keeps the water hyacinth or fails to destroy it in accordance with such notice as may be served upon him shall be guilty of an offence and shall be liable on conviction thereof to a fine not exceeding Rs. 100 or upon a second or subsequent conviction to a fine not exceeding Rs. 500. The Local Government may make rules prescribing the method by which and the time within which the destruction of the

water hyacinth shall be completed and prescribing the form and the terms of the notice to be served.

From the Administration Reports it appears that the Burma Government is also finding the Act difficult to apply.

Dacca District Board By-Law.

In 1919, the District Board of Dacca introduced a by-law to legislate for the disposal of water hyacinth. The by-law reads as follows :—

" 31 B. Any person having possession of, or control over, any land or water on or in which there exists any water hyacinth shall, if so required by a notice in writing signed by the Chairman or Vice-Chairman of the District Board, a Local Board or a Union Committee or by the District Engineer, destroy or remove such water hyacinth within the period mentioned in such notice. Provided that such notice (*a*) shall be issued simultaneously for the whole of an area to be defined by the District Board, a Local Board or Union Committee, and bounded by rivers or large *khals*, and (*b*) shall not be issued oftener than once a year."

The penalty attached to a breach of the by-law is a fine up to a maximum of ten rupees.

An additional by-law was proposed in November 1920, but it was not approved by Government. It read as follows :—

" 31 D. If the person upon whom notice has been served under by-law 31 B fails to carry out the order as required by the said notice, he will be liable to pay such costs as are incurred by the District Board, Local Board, Union Board, or Union Committee in order to remove or destroy the water hyacinth. Such costs will be recovered as other dues to those bodies are."

By-law 31 B fails in that it only stipulates that the hyacinth should be cleared once in a year. Experiments in tank clearing conducted by the Agricultural Department have shown that at least two clearings are necessary within a short interval as there are generally a number of plants missed in the first clearing.

At a meeting of representatives from District Boards held at Dacca in the beginning of this year opinion was against the

practicability of local legislation. One district is infected from another and it is difficult to impose penalties on individuals who can claim that the land was infected from up-stream. It was agreed that District Boards were powerless unless an Act on the lines of that introduced in Burma be introduced to apply to all India.

The subject was further discussed at a meeting of representa tives from all the District Boards in Bengal held in Calcutta in January 1921. A resolution was passed urging upon Government the necessity of passing an Act similar to the Burma Act. This induced Babu Nibaran Chandra Das Gupta to introduce a resolution in the Legislative Council regarding the appointment of the Water Hyacinth Committee, his contention being that Government could not penalize a man for not destroying water hyacinth until he had been shown the ways and means of destroying it.

Practical suggestions regarding collection, destruction and utilization.

Present methods of collection.

Bengal has not, so far, shown much in an original line in the way of method of collection, and this has been done by hand labour in all cases. In some cases the District Boards have allotted funds to pay labourers to clear waterways and in other cases cultivators and others have been stimulated to the task by warnings as to the danger to their crops and communications. The value as a manure has been an incentive to cultivators to collect the hyacinth in heaps until it rots and then to apply it on their land.

The elevator and grappler.

It will be seen from the note on measures taken in America that mechanical collection is advocated there. The two machines in use are the elevator and grappler, and there are many waterways in Bengal where the system employed in America would apply. These machines would be of importance if it were decided that

part of the money spent in destroying the hyacinth should be recouped by utilizing the plant for commercial purposes.

The present laborious method of clearing waterways and tanks by hand could be considerably lightened by the use of weed cutters and pond cleaners of which there are several on the market.

The erection of stoppage booms where plants floating down waterways may be checked and collected may also reduce labour and concentrate the work.

Present method of destruction.

Two methods of destruction are common in Bengal and both depend upon the plants having been first brought to dry land. The one is burning the plants after they have been dried and the other is rotting the plants in pits. Both are efficacious as long as no green plants are left to spring to life when the rains come. The majority of cultivators, when they are troubled with hyacinth on their land, just push it into the rivers. They may hope that it will reach salt water and there die, but it is generally destined to infest a neighbour's fields further down-stream.

Killing the plant by spraying solutions.

In America the spraying of the masses of floating plants with arsenical compounds has been accepted as the only method of killing the weed and keeping it in check. Objections have been raised to the danger of using poisons, and in Bengal, where every waterway is not only used by stock but also by the human population for washing and drinking purposes, the use of arsenical solutions becomes impossible.

Turning to the utilization of water hyacinth, the value of the plant as a manure and as a source of potassium chloride has already been discussed.

Manufacture of paper from dried water hyacinth.

The manufacture of paper from the dried hyacinth has lately been experimented upon in the Fibre Expert's laboratory. The samples of paper produced are promising, but as the percentage of pulp to dried plant is only 25 per cent. the value of water hyacinth

for paper making commercially is doubtful, unless it makes up into a special type of paper as the experimental samples suggest. In this connection the opinion of a leading paper manufacturer in England is quoted in the Commonwealth of Australia Circular No. 7. He reported on samples of water hyacinth sent to him that "it was the most inferior substance yet offered to him."

Preparing ink from the flowers.

In 1918 the Subdivisional Officer, Brahmanbaria, reported that blue-black ink had been prepared from the flowers of water hyacinth and that the colour changed to majenta red on treatment with acid and from red to green on treatment with soda. No method could be found of keeping the colours fast, and nothing further has been heard of the process.

Fodder for cattle.

The utilization of the green plant as cattle fodder is a common practice throughout districts where water hyacinth is plentiful at times when there is a scarcity of grass. The plants are pulled out of waterways and tanks and placed before the cattle in heaps. As far as has been observed the plants are not dried and preserved for fodder purposes. When grass is scarce, or in towns where the available grazing is liable to be fouled, it is a common sight to see the cattle wading into the tanks to graze on the hyacinth.

Utilization as fuel.

Many cultivators utilize the dried hyacinth for fuel. At the beginning of the cold weather the hyacinth is pulled out of their fields and the adjacent waterways, left on the high land to dry, and when dry used along with jute sticks and refuse as fuel. The ashes are subsequently used as manure.

Utilization in other countries.

Investigations into the possibility of putting water hyacinth to commercial use have been undertaken in other countries but do not bring any further enlightenment to bear on the subject. The various suggestions put forward have all proved to be of no

commercial value except its utilization as a source of potash. In Cochin China numbers of attempts were made to utilize the weed, amongst others the construction of furniture, the manufacture of ropes, and the manufacture of bags. These attempts were unsuccessful and it was concluded that its chief value was as a manure on account of the high percentage of nitrogen it contained. In New South Wales, paper manufacturers reported that it could only be used for straw-board and that sufficient other raw material was already available at 10*s*. a ton. Samples were supplied to firms of upholsterers who either condemned it or reported that it was only of use for the cheapest lines of upholstering, and would have to be marketed at a cheap rate. The Commonwealth of Australia Circular No. 7 of 1919 mentions an inventor who is patenting a process for the extraction of potash from water hyacinth in New South Wales. This process might be worth consideration.

Conclusion.

A glance at the attached map of Bengal (Plate III) will convince one of the dangers of the water hyacinth invasion in Bengal. The eastern part of the province with millions of acres over-flooded during the rainy season is especially susceptible to the pest. At the beginning a troublesome weed in the waterways, water hyacinth has now become a menace to the crops, and unless immediate steps are taken to eradicate it or at least to prevent its further spread, the whole of the deep-water paddy crop in Bengal will be endangered.

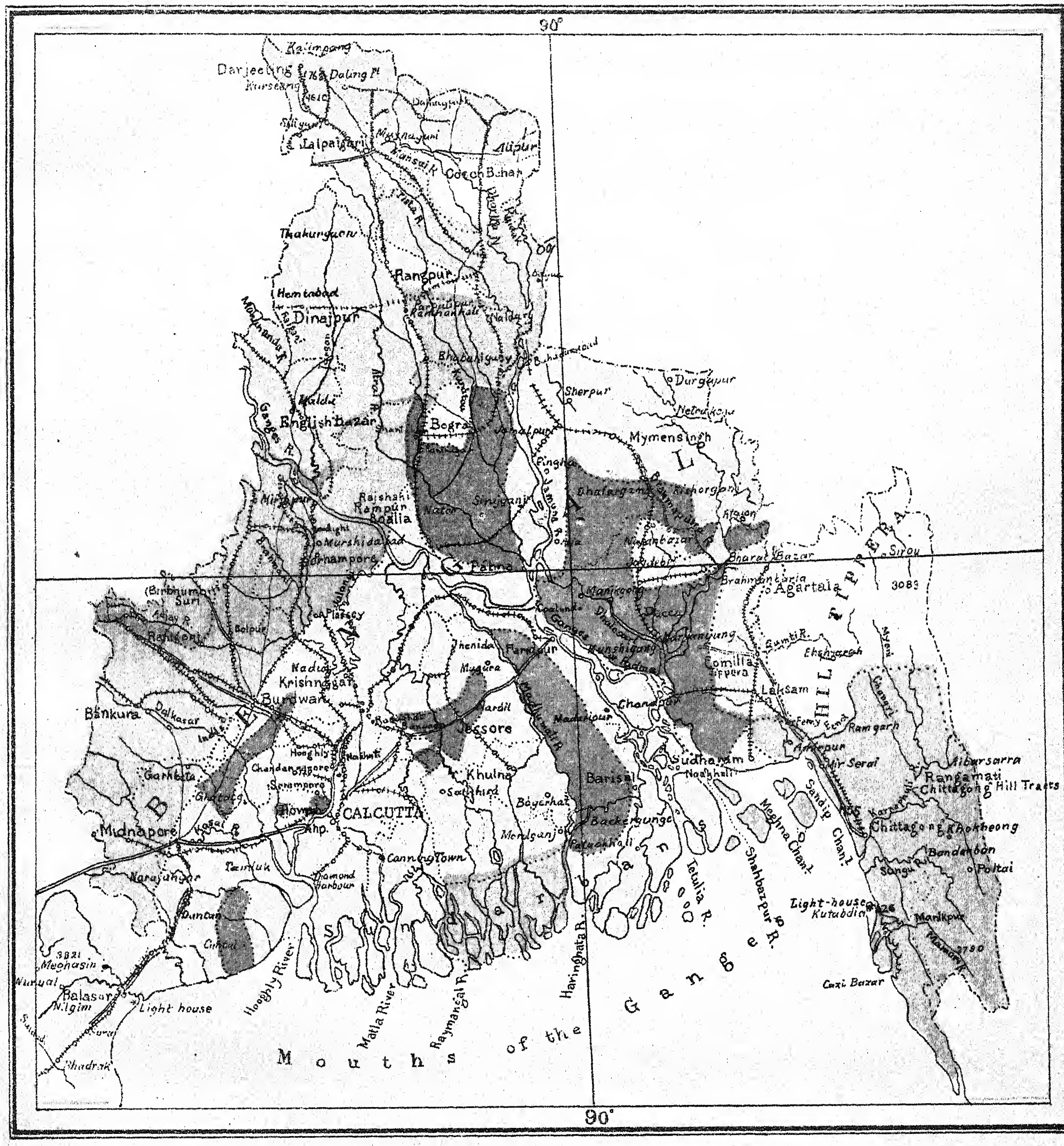
The reduction of the cost of eradication by utilization of the weed appeals to the economist. The danger lies in that the weed may not be properly destroyed if it obtains a commercial value, and that plants not destroyed will continue to spread the evil.

Nothing short of the complete destruction of the plant will save Bengal from this disastrous pest, and the findings of the Committee which is at present sitting in Bengal are awaited with interest. It is hoped that the recommendations will be put into immediate effect as it is felt that there has already been too much delay in tackling this vital problem.

MAP OF BENGAL

PLATE III.

SHOWING THE AREAS AFFECTED BY WATER HYACINTH.



Areas reported as very seriously affected.

Areas reported as less seriously affected.

Areas reported to contain weed in tanks, etc.

Areas reported to contain no water hyacinth.

A PRELIMINARY NOTE ON THE INCREASE OF GRAPE YIELD.*

BY

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Of the Department of Agriculture, Bombay.

In parts of Western India, and more especially in Nasik which is the chief grape-growing centre in the Bombay Deccan, the variety most common and prolific in yield is what is called *bhokri*. This variety, though much in demand on account of its availability and cheapness in the markets of Poona, Bombay, Nasik and Ahmednagar, is not, however, so fine and sweet as the varieties *fakadi* and *pandhari-sahebi* which are considered to be superior ones. Though the fruits of these fetch a better price, nearly twice as much as that of the local variety, their cultivation has not been on the increase, due chiefly to their extremely shy bearing nature. The question therefore arose early in 1914, as to how these varieties could be improved so as to be of commercial importance. Attempts were made to increase their yield, as well as the yield of the local variety *bhokri*, in the Ganeshkhind Botanical Garden, and the following is a résumé of the work done and the results obtained.

Methods of training as factors in influencing the yield.

The grape-vine requires some sort of training as it will not bear well if it lies on the ground. Various systems of training have therefore been adopted according to the fancy of the grower and the custom of the locality. The usual system of training

* Paper read at the Eighth Indian Science Congress, Calcutta, 1921.

adopted by Nasik cultivators is that on single-stake. In this system each vine is trained to a *pangara* plant (*Erythrina indica*) which forms a good living support (Plate IV, fig. 1). In Junnar (District Poona), the vine is surrounded by four *pangara* plants and is allowed to have four arms, each arm being trained to a *pangara* plant. This method is known as the Junnar method. The following are some figures of yield from plants in the Ganeshkhind Garden trained on these two methods :—

System of training	Name of the variety	Total No. of plants	No. of bearing plants		Total yield				Average yield per bearing plant			
			1919	1920	1919		1920		1919		1920	
					lb.	oz.	lb.	oz.	lb.	oz.	lb.	oz.
Single-stake	Bhokri	69	56	49	302	2½	209	15	5	6·3	4	4·5
Junnar	Do.	31	20	23	208	12½	95	13	10	7·0	4	2·6

Average yield per plant in the single-stake system for two years is 4 lb. 13·4 oz.

Average yield per plant in the Junnar system for two years is 7 lb. 4·8 oz.

In the Junnar system, the plants had been planted at the same distance as that in the single-stake system, *viz.*, 9 feet apart each way.

The Junnar method, though slightly better than the single-stake system as regards yield, entails a good deal of manual labour, as ploughing and other interculturing operations cannot be performed by bullock-power on account of the space being occupied by *pangara* plants. Other methods of training were started by Mr. G. B. Patwardhan, B.Sc., Assistant Professor of Botany, Agricultural College, Poona, from 1913, and these were (1) Umbrella, (2) Overhead and (3) Kniffin.

Umbrella system. In this system, the vine is trained to a strong wooden support in the centre, of the height of 6 feet, from the top of which several cross-bars pass at an angle of about 45° with the central support and are nailed down to four supports at the corners, the whole thus presenting the form of an umbrella

PLATE IV.

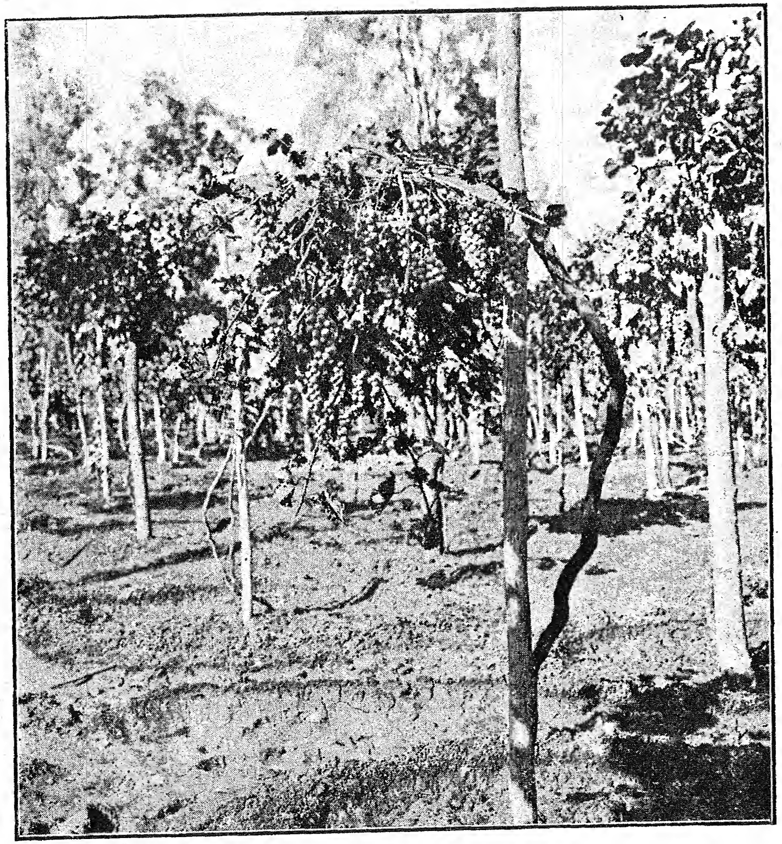

Fig. 1. Bhokri grape-vine trained on the single-stake system.

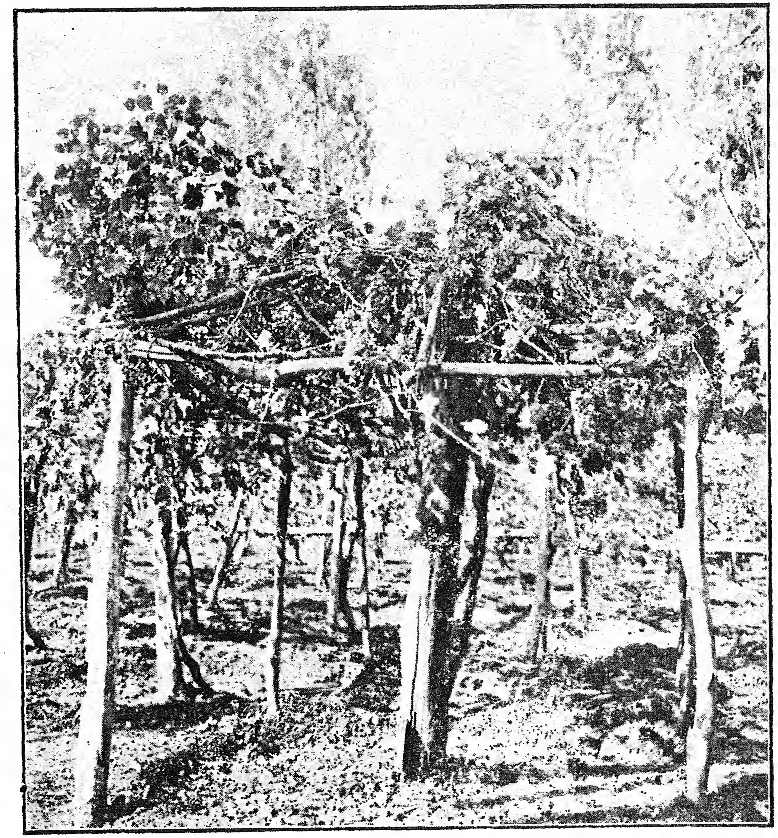

Fig. 2. Bhokri grape-vine trained on the umbrella system.

(Plate IV, fig. 2). Only six plants of *bhokri* variety had been so trained. The following are some figures of yield :—

Variety Bhokri : Umbrella system of training.

Plant No.	Age of the plant	Year of bearing	Total No. of bunches	Total yield lb.	Total yield oz.	Remarks
158	4th year ..	1916	78	19	13	
	6th ,, ..	1918	43	10	14	
	7th ,, ..	1919	63	16	10½	
	8th ,, ..	1920	132	13	8	Bunches were small in size.
168	4th ,, ..	1916	133	40	7	
	6th ,, ..	1918	70	14	0	
	7th ,, ..	1919	198	66	11	
	8th ,, ..	1920	8	2	1	Badly attacked by *Anthracnose*.

Average yield of plant No. 158 for four years is 15 lb. 3 oz.

Average yield of plant No. 168 for four years is 30 lb. 12¾ oz.

Variety Bhokri : Single-stake system of training.

Plant No.	Age of the plant	Year of bearing	Total No. of bunches	Total yield lb.	Total yield oz.	Remarks
165	5th year ..	1916	20	7	8	
	7th ,, ..	1918	4	7	2	
	8th ,, ..	1919	35	9	12	
	9th ,, ..	1920	3	0	10	
145	5th ,, ..	1916	40	8	1	
	7th ,, ..	1918	7	4	0	
	8th ,, ..	1919	29	7	0	
	9th ,, ..	1920	27	5	5	

Average yield of plant No. 165 for four years is 5 lb.

Average yield of plant No. 145 for four years is 6 lb. 1½ oz.

The following shows the comparative yield of the two systems :—

Variety Bhokri.

System of training	Total No. of plants	No. of bearing plants 1919	No. of bearing plants 1920	Total yield 1919 lb.	Total yield 1919 oz.	Total yield 1920 lb.	Total yield 1920 oz.	Average yield per bearing plant 1919 lb.	Average yield per bearing plant 1919 oz.	Average yield per bearing plant 1920 lb.	Average yield per bearing plant 1920 oz.
Single-stake ..	69	56	49	302	2½	209	15	5	6·3	4	4·5
Umbrella ..	6	6	6	222	1	53	2	37	0	8	13·6

From the above, it is clear that the umbrella system of training has given decidedly better results than the local system. It remains,

however, to be seen how far this system could be adopted on a field scale.

Overhead system. In this system, four canes of each plant are extended each in a different direction until they meet with the canes of the neighbouring plant. From each of these canes short spurs are developed, thus giving more room for the development of flowers and fruit. The following shows the comparative yield :—

Variety Fakadi.

System of training	Total No. of plants	Total yield	Average yield per plant	Amount of space covered by the plant
		lb. oz.	lb. oz.	3,267 sq. feet.
Single-stake ..	48	60 $1\frac{3}{4}$	1 4	
Overhead ..	48	170 $2\frac{1}{4}$	3 $8\frac{3}{4}$	„ „

Thus for the year 1920, the experiment has given definite results in favour of the overhead system of training, the average yield per plant being thrice as much as that on the single-stake system. Further results are, however, awaited before definite conclusions could be arrived at.

A slight modification of this system was adopted in the case of *pandhari-sahebi* variety which is a more vigorous grower than *fakadi*. The usual method of pruning adopted in previous years in this variety was the method of spur-and-renewal-spur. In October 1919, an experiment was started by the writer to keep the long canes formed during the rainy season after April pruning and prune them at their further end, *viz.*, after leaving 10 or 12 buds, instead of pruning them after 2 or 3 buds. The following are the results obtained :—

Variety Pandhari-sahebi : Age 7 years.

Method	No. of plants treated	Total yield	Average yield per plant
		lb. oz.	oz.
Spur-and-renewal-spur ..	17	3 8	3·2
Long spur	18	15 $6\frac{1}{2}$	13·6

The results, though they are of one year, show in favour of the long-cane system. Maney says[1]: "Grape-pruning experiments carried on near Council Bluff's during the season of 1914, for a comparison of the spur with the long-cane and renewal-spur system, showed that the vines pruned after the long-cane system yielded, on the average, 41 per cent. more grapes than the spur pruned vines. These results indicate that the long-cane system is of value for the south-western and other sections of Iowa where grapes are grown." However, it must be recognized that these results are for one year only. Further experiments with the two systems must be carried on before the long-cane system can be recommended unreservedly.

Kniffin's or drooping system. This system, named after William Kniffin of Clintondale, consists in training the vine to posts, six feet in height, set by each vine. Two wires or horizontal bars are fixed, the one about three and a half, the other about six feet from the ground. One main stem is grown from the ground to the upper wire. Only two branches are allowed on each wire, one on each way, the rest being removed. Four arms are thus encouraged and these are firmly tied to the wire and are extended to a length of 3 or 4 feet until they meet with their neighbours. Any shoots springing from each bud are allowed to hang down with their clusters of growing grapes. This method is much in practice in America and is said to have a distinct merit for strong growing varieties. It was adopted in the Ganeshkhind Botanical Garden, Kirkee, in the year 1912. The following statement shows some outturn statistics :—

System of training	Name of the variety	Total No. of plants	No. of bearing plants		Total yield		Av. yield per bearing plant	
			1919	1920	1919	1920	1919	1920
					lb. oz.	lb. oz.	lb. oz.	lb. oz.
Single-stake ..	Bhokri	69	56	49	302 2½	209 15	5 6·3	4 4·5
Kniffin ..	,,	12	11	4	184 9	10 15	16 12	2 11·5
Single-stake ..	Fakadi	48	14	27	97 10½	60 1¾	6 15	2 3·7
Kniffin ..	,,	16	13	15	76 10	36 1	5 14	2 6·4

[1] *Agri. Expt. Stn. Iowa Bull.* 160, Oct. 1915.

This system has not shown any decided advantage over the local system of training except in the year 1919, when the average yield of a *bhokri* plant was nearly three times as much as that on the single-stake system.

STUDY OF THE POLLEN AND METHODS OF RINGING AND COILING IN INCREASING FRUITFULNESS.

Apart from the methods of training adopted, other lines of increasing the grape yield were carried out. In the varieties noticed in the Ganeshkhind Botanical Garden, Kirkee, two classes of grape clusters were seen to exist, *viz.*, (1) clusters with closely set fruits and (2) clusters with berries set wide apart (Plate V, figs. 1 and 2). It was at first suspected that, in the loosely set clusters, the flowers may be sterile.

This self-sterility (entire or partial) was studied by Professor Beach. He says[1] : " Many of the cultivated varieties of American grapes are either self-sterile or very imperfectly self-sterile. In discussing the practical bearing of these discoveries upon the selection of varieties and arranging them in vine-yards so as to get the best results in fruit production, attention was called to the fact that self-sterile varieties may produce well-filled clusters of fruit when the vines are located near enough to other kinds to make cross-fertilization possible." The subject was further studied by Mr. Booth who states[2] : " (*a*) The self-sterility which is known to exist among many varieties of cultivated grapes is, in many cases, if not all, due to a lack of potency in the pollen. (*b*) This lack of potency is indicated in the pollen grains by a shape which is quite different from that of potent pollen. (*c*) Certain varieties of grapes bear pollen in which both the potent and impotent forms are mixed." He further states : " The self-sterile grains seemed to be surrounded by a mucilaginous substance which makes them stick to one another more or less so that the pollen whether it lies dry on

[1] *New York Agri. Expt. Stn. Bull.* 157.
[2] *New York Agri. Expt. Stn. Bull.* 224.

PLATE V.

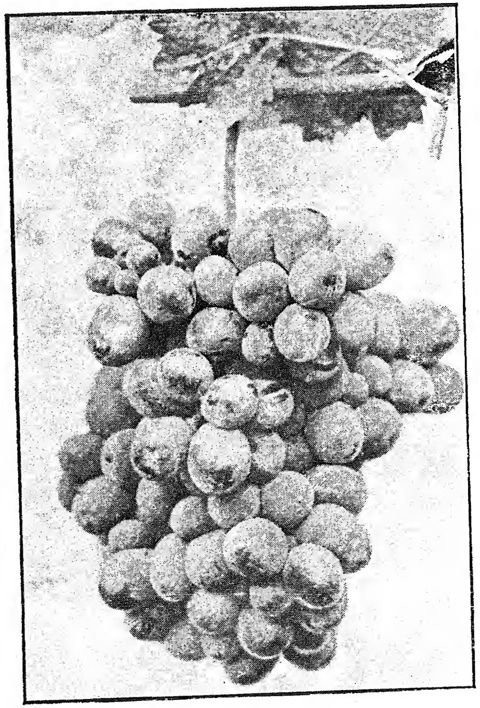

Fig. 1. Closely set bunch of grapes; variety Bhokri.

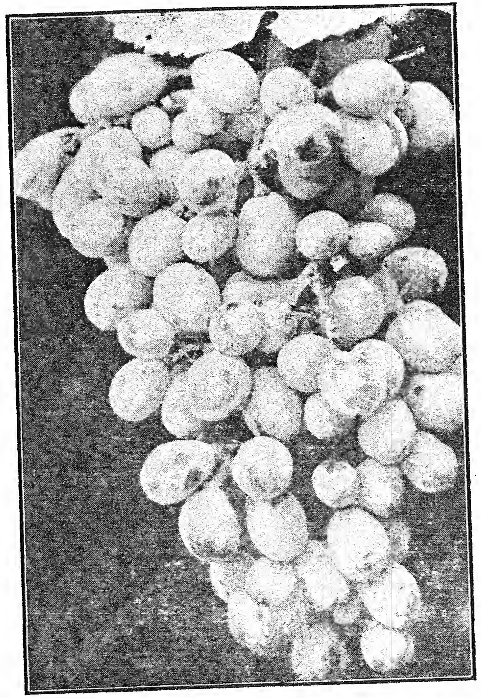

Fig. 2. Loosely set bunch of grapes; variety Pandhari-Sahebi.

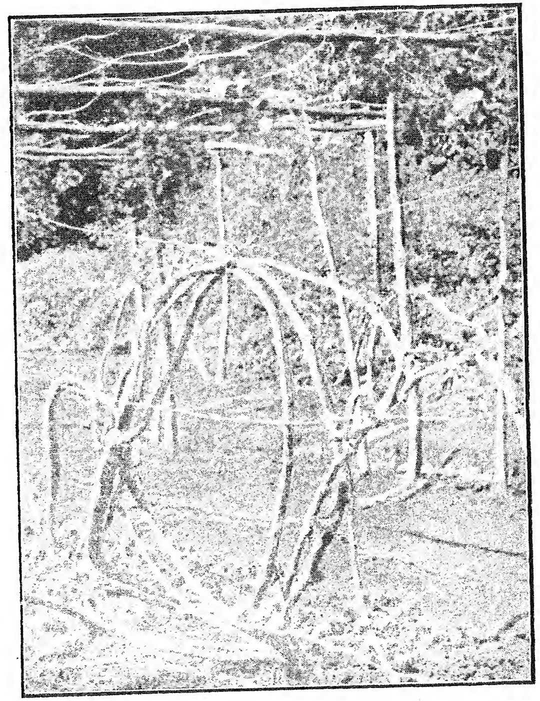

Fig. 3. Coiling of grape-vines to stimulate the buds.

the slide or is placed in liquid media arranges itself in a succession of clumps. This mucilaginous substance does not appear to be soluble in water, as the pollen grains retain their respective positions even after several days in the solutions. The self-sterile pollen, on the other hand, shows no such arrangement but the grains distribute themselves either on the slide or in the liquid like so much dry powder, quite by chance. The self-fertile forms are oblong, blunt at the ends and quite symmetrical. The self-sterile sorts are quite different in shape, being more irregular and usually more pointed than those of the other class."

I set to work on the lines suggested above in November 1919, but my laboratory examination of the dry pollen grains did not reveal any characteristic differences in the size or shape of the different classes of pollen. As the blooming season of the grape is very short, my observations were, moreover, limited.

At the present stage it may fairly be said that the flowers of varieties existing in the Ganeshkhind Botanical Garden were not found to be self-sterile. Other attempts, therefore, of improving the yield adopted in foreign countries, *viz.*, girdling or ringing and coiling the branches had to be adopted.

Girdling. This consists in the removal of a ring of bark to a width of half to one inch. The principle of this is to concentrate a large amount of elaborated food material in the portion of the branches situated above the ringed area and thus stimulate them to bear flowers and fruits. It is practised by the Greeks to promote setting of fruit, uniformity of bunch, and increased size of berry.[1] In the work done by the writer, a narrow ring of bark to a width of ½ to 1 inch was taken from the fruiting canes of the *pandhari-sahebi* variety between the first and second nodes. The operation was done immediately after pruning on October 22, 1919, and also when the leaves had appeared, *viz.*, on 18th and 19th November, 1919.

[1] *Garden and Field* Australia, cited in *Pac. Coast Fruit World,* May 24, 1901.

Besides the above, the operation of coiling the canes was also done. This is usually done, in the Ganeshkhind Botanical Garden, in the case of grape plants on bowers and has become an annual operation (Plate V, fig. 3). It had not however been done on the shy bearing varieties. In order to ascertain its efficacy on the *pandhari-sahebi* variety, the canes were severely coiled so as to form two or three circles and firmly tied in position by means of a string. The following shows the results obtained :—

No.	Nature of the operation	No. of shoots treated	Yield	
			lb.	oz.
1	Coiling the canes	43	6	6½
2	Ringing the spurs immediately after pruning ..	38	0	5
3	Ringing the spurs when new growth had formed ..	34	0	8
4	Long rods kept	36	8	1

Though the above are the results of one year's trials, they indicate that ringing even before or after the formation of leaves failed to give good results in the case of the variety *pandhari-sahebi*.

INFLUENCE OF STOCK ON THE YIELD.

Mr. H. V. Gole, the well-known grape grower of Nasik, tried the grafting methods and has found that *fakadi*, when grafted on *bhokri*, yields 2 lb. more than the average yield on its own roots.[1]

The experiments conducted in the Ganeshkhind Botanical Garden are inconclusive.

YIELD IN RELATION TO MANURING.

In order to ascertain the efficacy of some manures in increasing the grape yield, experiments were started in the Ganeshkhind Botanical Garden, Kirkee, in 1912.

[1] *Agri. Jour. India*, XIV, pt. I.

Variety Bhokri : treated in Oct.-Nov. 1912.

No.	Manure given per tree in one dressing	No. of plants treated	No. of bearing plants	No. of bunches	Total wt. of bunches		Yield per bearing plant	
					lb.	oz.	lb.	oz.
1	Fish manure 8 lb. .. Sulphate of potash 1 lb. ..	6	6	28	9	3	1	8½
2	Fish manure 8 lb. ..	6	6	13	3	12	0	15
3	Farmyard manure 20 lb. ..	6	4	10	2	13	0	11
4	Safflower cake 8 lb. .. Sulphate of potash 1 lb. .. Bonemeal 2 lb. ..	6	4	21	3	8	0	14
5	Safflower cake 8 lb. .. Bonemeal 2 lb. ..	6	6	39	13	1	2	3
6	Sheep dung 20 lb. ..	6	6	17	4	2	0	11
7	No manure ..	16	6	17	3	14	0	10

The plants were planted in February 1911, *i.e.*, the fruiting above referred to occurred when they were just two years old and was not therefore up to normal.

The results of 1912 showed in favour of treatments 1 and 5, and hence these two were selected for experiment in 1913 against farmyard manure by itself.

Variety Bhokri : manured October 1913.

Manure given per tree	No. of bearing plants	Total yield		Yield per bearing plant		Yield per bearing plant' 1912-1913	
		lb.	oz	lb.	oz.	lb.	oz.
Farmyard manure 80 lb. ..	23	61	0	2	10½	0	11¼
Fish manure 8 lb. .. Sulphate of potash 1 lb. ..	23	72	0	3	2	1	8½
Safflower cake 8 lb. .. Bonemeal 2 lb. ..	28	55	13	2	0	2	3

As the flowers appeared soon after pruning, it was found doubtful if manures applied in October really affected the amount of

flowering. Hence it was decided in 1914 to apply manures *after the April pruning* so that they may be effective in producing strong bearing wood for the next season.

Variety Bhokri : manured April 1914.

Manures given per plant	No. of plants (bearing)	Total yield	Yield per plant
		lb.	lb.
Farmyard manure 80 lb.	25	159	6·4
Fish 8 lb. and sulphate of potash 1 lb. ..	25	199	8·0
Safflower cake 8 lb. and bonemeal 2 lb. ..	25	154½	6·2

The two years' results show in favour of a combination of fish manure and sulphate of potash.

CONCLUSIONS.

The following conclusions are arrived at :—

(1) The umbrella system has so far been found to give better yield than others in the case of *bhokri* variety. It remains yet to be seen how far this system could be adopted on a field scale.

(2) In the year 1919-20, the overhead system of training has given three times as much yield per plant as that on the single-stake in *fakadi* variety, the amount of space occupied being the same in each case.

(3) The Junnar system has given a better yield than the single-stake system but entails a good deal of manual labour.

(4) Examination of the pollen grains of *fakadi* and *pandharisahebi* variety did not show the characteristics noticed in the flowers of partially sterile varieties in America.

(5) Among the manures tried, a combination of fish manure and sulphate of potash has given favourable results.

PLATE VI.

Fig. 1. A chilli plant attacked by the *murda* disease.

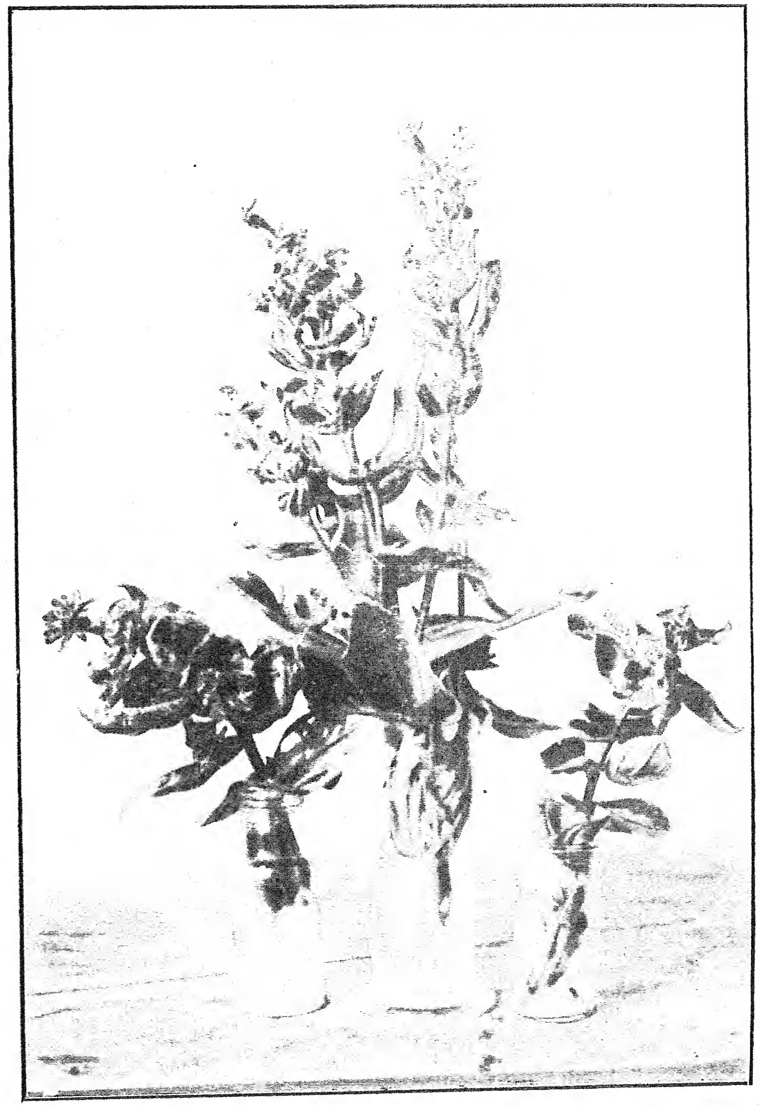

Fig. 2. Zinnia plants attacked by the chilli mite.

THE "MURDA" DISEASE OF CHILLI (*CAPSICUM*).*

BY

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This is a very serious disease, nay, in fact the greatest enemy of the chilli plant, occurring in most parts of the Bombay Presidency. It is, therefore, well known to the cultivators who call it by various names as *murda, goja, macoda* and *mirya* in the Deccan, *chandiroga* or *mutlagariroga* in the Karnatak, and *kokadva* in Gujarat.

The disease makes its appearance first in the terminal or axillary tender shoots of the plants. The leaves of the attacked shoots get curled up usually outwards and droop down (Plate VI, fig. 1). Often they show much distortion and wrinkling and are reduced in size. They gradually dry up and drop down. New shoots come up, which are in turn attacked and destroyed. The growth of the plants is thus checked. The disease appears at any stage of the plant. If it begins at the seedling stage the affected plants never produce any flowers and fruits. If the plants are attacked in the flowering stage most of the diseased flowers wither and drop down and the few that escape form berries which are also soon spoiled. The attacked fruits are much smaller than the normal ones and are curved. The disease gradually spreads to the lower branches, and as the internodes of the attacked branches are shortened the leaves appear as if they are in clusters and are reduced to minute scale-like structures. In such a highly malformed stage the plant at times is

* Paper read at the Eighth Indian Science Congress, Calcutta, 1921.

recognized with great difficulty. Such a severe attack was noticed this year (1920) near Poona in the Baramati valley where in most of the fields the crop was a failure. Reports of ravages of this disease have also been received from the tracts of Bijapur, Gokak, Kolhapur, Khed, Amalsad and Anand.

The cause of this disease is the same mite which causes the *tambera* disease of potato.[1] That the potato mite has something to do with the chilli trouble was suspected by the writer while the *tambera* disease was being studied in the year 1919, but an attempt to produce the disease in chilli plants by inoculation experiments was not successful as mentioned in the previous paper, probably because the experiments were done rather late in the season. The study was therefore postponed for the next year. Early in June 1920, the disease was noticed on the chilli seedlings in the writer's compound, and an examination of the diseased plants gave clear proofs of the presence of a mite agreeing in all its stages with that on potato. Inoculation experiments were therefore at once started. Three sound, twenty-days-old potato plants in pots were taken. Two were used for inoculation and the third for control. Inoculation of the plants was made by putting on them affected parts of the chilli plants containing the mites. The infected plants began to show on the ninth day distinct symptoms of attack, *viz.*, the twisting and curling of the leaves with a reddish tinge and the erect bunching habit of the shoots (Plate VII, fig. 1), and on the thirteenth day the tender leaves on one plant began to dry up; on the sixteenth day the affected shoot was completely killed. The control plant remained healthy during this period. Experiments were then made with chilli plants which were inoculated with the potato mite. Six sound chilli plants in pots were chosen, four for inoculation and two for control. Inoculated plants on the 12th day began to show the typical symptoms of the *murda* disease. The leaves became twisted and crumpled, were much reduced in size and had a number of moving mites on them. The control plants remained quite healthy all the while.

[1]Mann, Nagpurkar and Kulkarni. The *Tambera* Disease of Potato. *Agri. Jour. India*, XV, pt. III.

Fig. 1. Potato plants showing the *tambera* disease when inoculated with the chilli mite.

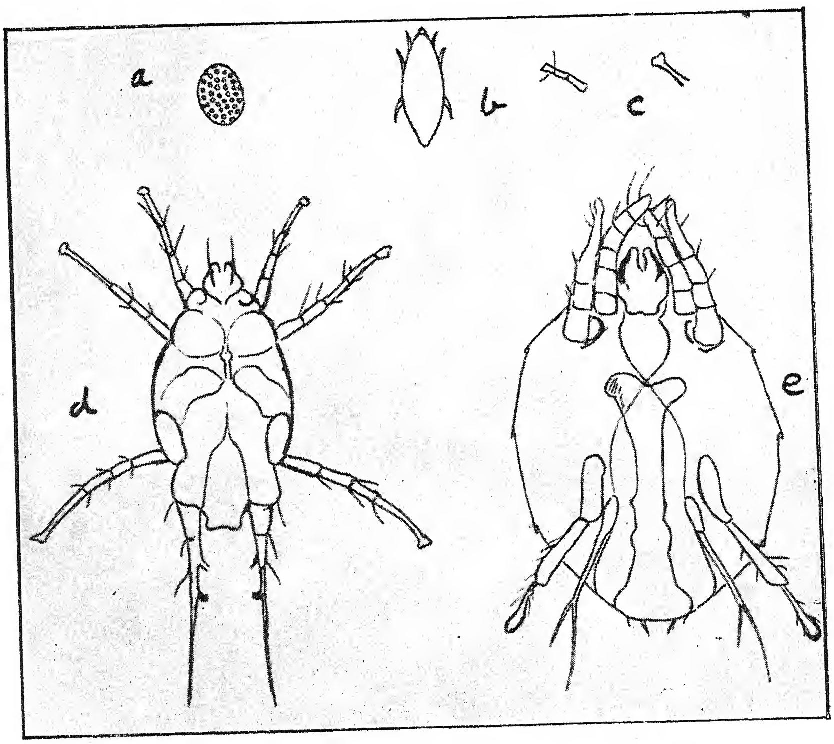

Fig. 2. The chilli mite in all its stages. a, egg; b, young one; c, tips of legs showing hooks and gland; d, male mite; e, female mite.

The cause of this disease, which had baffled our efforts so long, having been discovered, attempts were at once made to treat the diseased plants with the lime-sulphur wash. Spraying experiments were made at seven different centres in the Presidency—Gokak farm and Goshanhatti in the Belgaum District, Tikkoti and Muttagi in the Bijapur District, Baramati and Karkumb in the Poona District and at Rukdi in the Kolhapur State. Only one spraying was given. Favourable reports as to the efficiency of the treatment were received from all the above places. The results were most successful especially at Gokak and Rukdi, while in other places they were not so marked as the disease was in a far advanced stage at the time of treatment. These preliminary trials show that only one spraying is enough to control the disease if done at the time when the disease just appears. The cost of spraying per acre came to Rs. 10.

Search for other host plants of this mite has shown that besides *guar* (*Cyamopsis psoralioides*) as mentioned in the previous paper, it occurs on Zinnia, Dahlia, Tagetes, *Mirabilis jalapa*, Cape gooseberry, *Amaranthus polygonus* and *Physalis minima*. In the case of Zinnia, the affected plants get stunted in growth, the leaves are twisted and crumpled in various ways and no flowers are borne (Plate VI, fig. 2). If the flowers appear, they are few and are much reduced in size. Often the flowering parts are transformed into leafy shoots. Early in the season this year, a few affected Zinnia plants in front of the Agricultural College buildings, Poona, attracted the writer's attention, and examination of these showed on the under-surface of the leaves any number of moving mites agreeing with those on chilli. Cross-inoculation experiments were made, using the mite obtained from one host to inoculate the other. The results were quite successful, showing the typical symptoms of the disease in each plant. The Zinnia disease was one of the constant complaints received from the public, and the worst attack noticed in Poona during the last six years occurred this year (1920) in the Government House Gardens, Ganeshkhind, where all the Zinnia plants were completely spoiled. Its ravages were also reported from the Victoria Gardens, Bombay. No spraying trials were undertaken

as the season and the disease had far advanced when the reports were received.

As the mite has already been described in the previous paper,[1] it is not necessary to repeat the description here.

It is hazardous, no doubt, to attempt to identify the mite, as it is the work of a specialist. However, the following is the venture made by the writer.

In the Indian literature on mites a Litchi disease has been described by Misra.[2] The mite in the attacked parts of the plant causes a peculiar hairy growth and it is said to be a species of *Eriophyes*. There is another disease on cotton and jasminum. Here too in the attacked parts the mite produces woolly growth and it is said to belong to a species of *Phytoptus*. The chilli mite differs both in its morphological characters and in the effects produced on the host from these two species. Carpenter's[3] statement that the mite may belong to a red spider group (Tetranychidæ) does not seem to hold good. The Tetranychidæ[4] have six segments in their legs, while the legs of this mite have five segments (Plate VII, fig. 2). The mite comes very near to the yellow mite of the genus *Tarsonymus* described by Watt and Mann.[5] The description and illustrations of the yellow mite agree completely with those of this mite. The peculiar sucking discs with two hooklets at the end of the legs—characteristic of Tarsonymidæ[6]—are also noticed. It may therefore be a species of Tarsonymidæ.

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[1] *Agri. Jour. India*, XV, pt. III

[2] *Agri. Jour. India*, VII, p. 286.

[3] A New Disease of the Irish Potatoes. *Phytopathology*, VIII, p. 286.

[4] Brown, Max. *Animal Parasites of Man*, 1906, p. 355.

[5] Watt and Mann. *Pests and Blights of Tea Plant*, 1903, p. 360.

[6] Brown, Max. *Animal Parasites of Man*, 1906, p. 356.

Selected Articles

ARTIFICIAL FARMYARD MANURE.*

BY

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As a consequence of the campaign for increased food production during the war, and the resulting extension of the area under cereal crops, it was thought that, even after making allowances for disposal through the usual channels, there might still remain a surplus of straw which could not be utilized for feeding or for conversion into manure. It was, therefore, determined to investigate the possibility of converting straw into manure without the intervention of live stock, and a special grant-in-aid of the investigation was made to the Rothamsted Experimental Station by the late Food Production Department. Apart from war conditions, the possibility of adding to the supply of organic manure deserves consideration. In the case of market gardens particularly, the difficulty of obtaining adequate supplies of stable manure is increasing. The investigations described below indicate a method by which straw can be converted into a substance having many of the properties of stable manure. Further experiments to test the economic value of the process when conducted on a large scale are in progress at Rothamsted. Lord Elveden has also generously provided assistance and facilities for experimental work on his Pyrford estate.

* Reprinted from *Jour. Min. Agri.*, XXVIII, no. 5.

Of a considerable number of preliminary experiments to secure obvious breakdown and colour changes in fermenting straw, the most promising results were obtained when straw was subjected to the action of a culture of aerobic cellulose-decomposing organisms (*e.g.*, *Spirochæta cytophaga*). Further enquiry showed, however, that this effect was not due simply to the provision of an organism capable of breaking down cellulose, but rather to the indirect effect of the mineral substances contained in the culture fluid. From this point on, the question of food supply—as distinct from the addition of any particular species of organism—received special attention, and, as will be seen later, led to results possessing both theoretical and practical importance.

Without entering into a detailed account of the various stages of the investigation, we may state here that the most essential factors making for the production of well-rotted artificial farmyard manure are air supply, suitable temperature, and a suitable supply of soluble nitrogen compounds.

(1) *Air supply.* It has been found invariably that characteristic breakdown changes in straw remain suspended when a free supply of air is excluded either by intense consolidation or by immersion of the straw in liquid. The fermentation appears, therefore, to be an essentially aerobic one, at least in its early stages, and the typical disintegration of the straw with the production of dark-coloured plastic material does not take place in the absence of air. Moreover, the colour of the aerobically produced manure is rapidly reduced when oxygen is excluded. The great importance of air supply is shown by the following experiment, in which four lots of straw were fermented under aerobic and anaerobic conditions for three months at 37°C. (99°F.).

	Loss of dry matter	
	Straw without nitrogen	Straw with nitrogen
	Per cent.	Per cent.
Without air supply	16·3	17·1
With air supply	40·1	59·8

The data explain what may be seen in the ordinary heap of farmyard manure, *viz.*, that straw submerged in liquid urine, and therefore protected from air, remains in an unchanged state for long periods. On the other hand, the practice of carting manure from the yards and boxes and storing it in heaps in the field, although carried out for other reasons, provides better conditions for rotting than are likely to prevail where the dung is consolidated by trampling and saturated with urine.

(2) *Suitable temperature.* Except in those cases where straw is being fermented under otherwise unfavourable conditions, special measures to maintain a favourable temperature for fermentation are not called for. In common with other fresh fermentable materials, moist straw rapidly undergoes a preliminary fermentation during which the temperature may rise to upwards of 65°C. (149°F.). It is, however, in the subsequent stages that the effect of treatment becomes most evident in maintaining the temperature. Experience has shown that a supply of nitrogen, by increasing the energy of fermentation, leads to an increase of 15–20° C. (59–68° F.) in favour of straw which has received a sufficient supply of nitrogen, as compared with untreated straw.

(3) *A supply of soluble nitrogen compounds in suitable concentration, and possessing a neutral or slightly alkaline reaction.* Repeated experiments have shown that the most rapid breakdown of straw occurs when some source of nitrogen in an available or indirectly available form was supplied, and then only in those cases where the reaction of the solution was neutral or slightly alkaline. Hence the supply of nitrogen in the ammonium sulphate alone fails to lead to definite breakdown since the medium soon becomes markedly acid, while, on the other hand, the supply of an alkaline compound alone, such as caustic soda, is equally ineffective, since a source of nitrogen is lacking. The addition of nitrogen in the form of urine, urea, ammonium carbonate, or peptone within certain concentrations immediately sets in train rapid decomposition changes, and results within the period of a few weeks in the production of dark-coloured, well disintegrated, structureless material closely resembling well-rotted manure. That this should

be the case with urine was perhaps not remarkable, although the factors which operate in the essential dung-making process had not then been individually worked out, but that an essentially characteristic product could be obtained without the use of urine or of the fæcal portion of the manure as ordinarily produced was at once suggestive. On the basis of subsequent work, it may indeed be claimed that, in the production of normally well-rotted farmyard manure, the mass inoculation of the litter with the large bacterial population of the fæces does not exert any marked contributory influence on breakdown changes ; that the urine, as such, apart from being the carrier of nitrogen, does not induce any characteristic changes in the straw, while the typical smell and colour of stale urine from the manure heap may be successfully reproduced from straw treated with ammonium salts.

Although it is important that available nitrogen should be present for the rotting process, it is also not less essential that the quantity of nitrogen should not exceed a definite amount both actually as well as in concentration. In other words, if the concentration of ammonium carbonate produced from the decomposition of urine or urea exceeds a definite limit, not only are straw-breakdown changes definitely held up, but they continue to be inoperative until by volatilisation, and consequently loss of nitrogen to the air, the concentration or alkalinity has been reduced to the upper limit of growth of micro-organisms. *This must be regarded as particularly important, since the highest concentration for rapid breakdown is appreciably below that of the weakest undiluted urine.*

It follows that it is quite impossible to produce well-rotted dung by the use of neat urine without considerable losses. This fact may be illustrated by the following table, and, incidentally, is shown by all the investigations that have been carried out on the making of farmyard manure.[1] Three equal portions of straw were saturated either with water or urine and allowed to ferment for three months in the laboratory, the two portions with urine being subjected to different temperatures. As will be seen from the

[1] See, for example, Russell and Richards, *Jour. Agri. Sci.*, 1917, VIII, p. 495.

following table, these two portions fermented to different degrees —the dry matter losses being 49 and 60 per cent. respectively, *but the final nitrogen content was almost identical*, and practically three-fourths of the nitrogen supplied as urine was lost.

Temperature	Loss of dry matter	Nitrogen		
		Initial	Final	Loss—or Gain +
	Per cent.	mg.	mg.	mg.
Straw with water (36°C. = 97°F.)	40·1	71	97	+ 26
,, ,, urine (26°C. = 80°F.)	49·1	507	178	– 329
,, ,, ,, (36°C. = 97°F.)	59·8	507	176	– 331

It would be erroneous, however, to assume that such losses are inevitably connected with a satisfactory breakdown of straw, or that the conditions ordinarily obtaining in the farmyard at all represent optimum proportions between the straw which is to be decomposed, and the concentration of nitrogen in the urine which eventually serves for this decomposition. That equally good rotting may be obtained without loss of nitrogen is shown by the cases given in the table below. In the experiments to which the table refers, straw was incubated with urine in different concentrations for periods up to 86 days. Even after this period the losses that occurred with satisfactory rotting and within the lower concentrations were only about 4 per cent. of the total nitrogen of the final product. The ordinary losses of the manure heap are frequently more than tenfold this amount.

	Number of experiment				
	(1)	(2)	(3)	(4)	(5)
At beginning— Straw and urine nitrogen	77·5	157·6	237·6	317·6	397·6
After 86 *days*— Total nitrogen	77·3	153·1	226·8	262·1	308·0

In addition to *the two phases already mentioned*, (a) in which straw overloaded with nitrogen loses it to a definite degree, and (b) in which straw with the requisite amount of nitrogen may undergo rotting without appreciable loss and is therefore in a state of

equilibrium, there exists *a third phase* in which under-saturated straw, by the agency of micro-organisms, exhibits a well-marked property of picking up nitrogen, particularly in the form of ammonia, until the same final content of nitrogen in the rotted product is attained. Hence we might expect that in two different but adjacent portions of fermenting straw, the one overloaded with, and the other lacking, nitrogen, the former portion loses and the latter accumulates nitrogen until a common level is approached. That such is actually the case is illustrated by the following data, and is diagrammatically represented in Fig. 1. Ten portions of

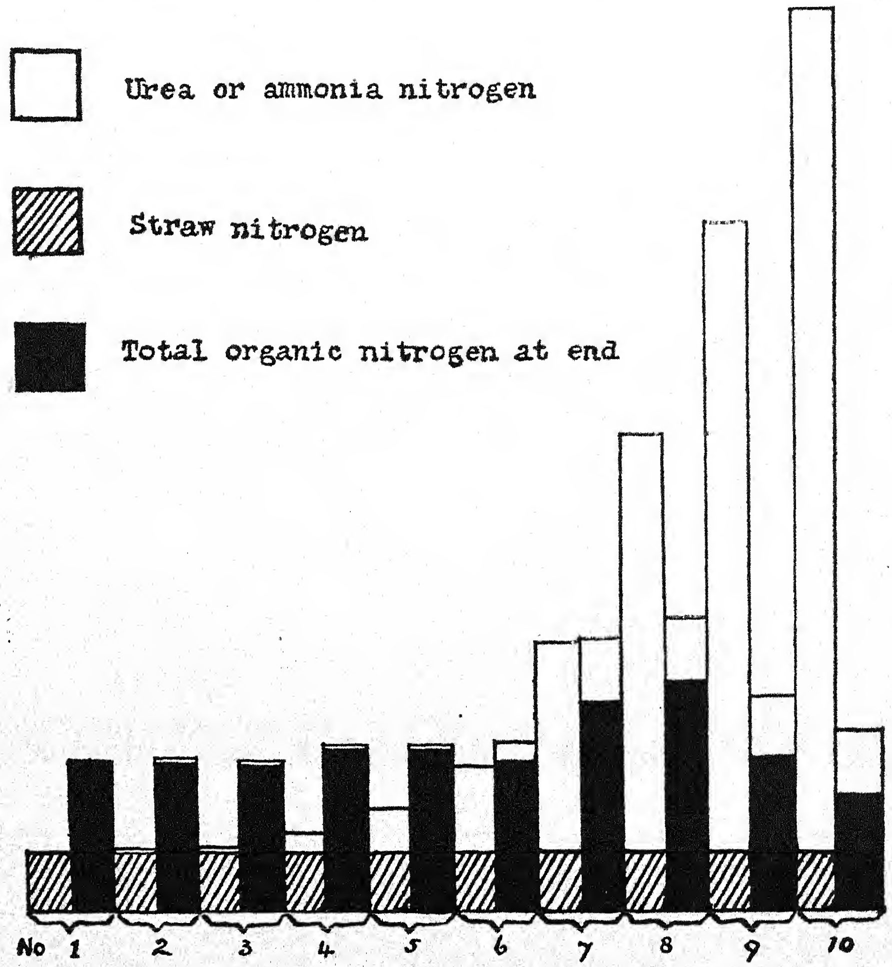

FIG. 1. The diil aagrlustrates the power of under-saturated straw to pick up ammonia lost by super-saturated straw. Ten portions of straw with increasing quantities of nitrogen (as urea) were allowed to ferment for three months.

straw were moistened to the same extent, and while one received water only, the others received additions of soluble nitrogen in the form of urea in varying quantities, until the last portion was saturated with a solution similar in concentration of nitrogen to that of horse urine (1 per cent. of nitrogen). The different portions were then kept in an incubator for 3 months, at the end of which time it was evident that, contrary to expectation, the straw, without or merely with low doses of nitrogen, had passed through a marked rotting process. On analysis, however, it was found that there had been a definite accumulation of nitrogen in the lower members of the series, while the higher members had lost in some cases the greater portion of their original nitrogen.

The decomposition of straw in the presence of varying quantities of nitrogen as urea.

	Number of experiment									
Treatment ..	1	2	3	4	5	6	7	8	9	10
At beginning										
Straw nitrogen mg.	71	71	71	71	71	71	71	71	71	71
Urea nitrogen ,,	—	5	10	24	48	97	243	486	729	973
Total nitrogen ,,	71	76	81	95	119	168	314	557	800	1,044
At the end of 3 months										
Organic nitrogen mg.	180	177	174	190	192	171	245	269	181	134
Ammonia ,, ,,	—	5	2	4	4	29	74	68	71	76
Total ,, ,,	180	182	176	194	196	200	319	337	252	210
Gain or loss ,,	109	106	95	99	77	32	5	—220	—548	—834
Dry matter, loss per cent.	49	46	45	49	47	53	51	48	19	14

In seven out of the ten cases the final nitrogen of the fermented straw varied only between 180 and 210 mg., irrespective of the nitrogen content of the original mixture. It should also be noted that the extent of the rotting, *i.e.*, the loss of dry matter, in experiments 1–8 was very much greater than in 9 and 10 in which the straw was subjected to the action of solutions closely approaching

the concentration of ordinary urine, the high alkalinity of the latter exercising a check on decomposition.

In the main, the nitrogen retained by super-saturated straw, or such as is accumulated by under-saturated straw, as in Nos. 1–6 in the above table, appears to be stored up in an organic or non-ammoniacal form. The maximum retention has been found to occur within the first four weeks, after which time breakdown of this organic nitrogen to ammonia and consequent loss by volatilisation seems to keep pace with loss of dry matter. Finally, the material assumes a "stabilised" condition—the loss of nitrogen becomes greatly diminished or may be absent altogether for long periods. These three phases—accumulative, dispersive and stable—are shown in Fig. 2, which illustrates the type and extent of the

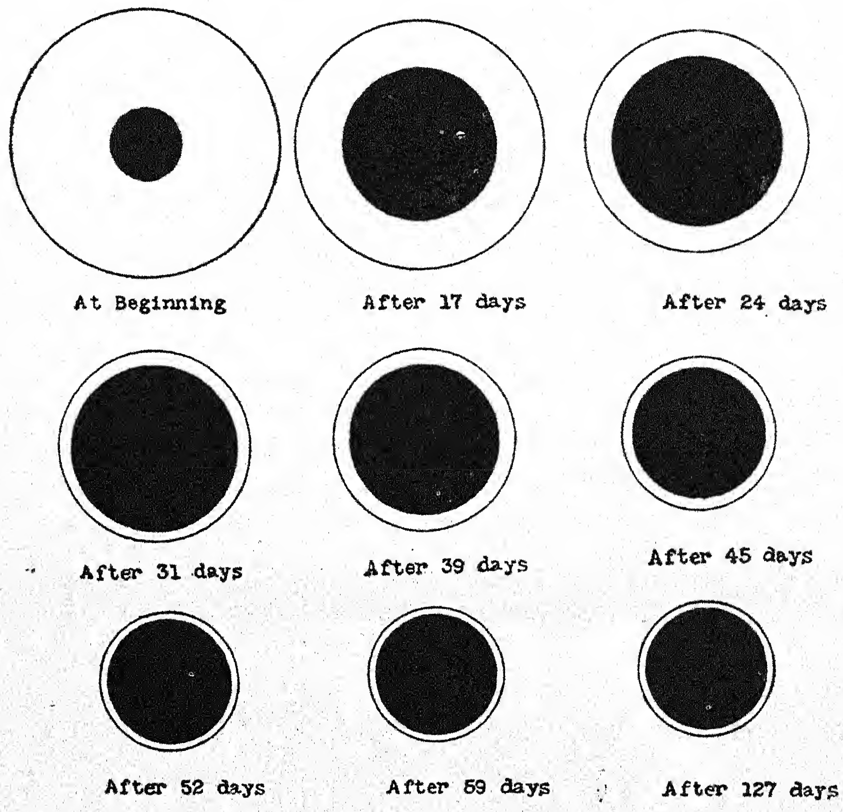

FIG. 2. The diagram illustrates the changes that occur when straw is fermented in the presence of urine. The black discs represent fixed nitrogen, and the white outer circles represent ammonia nitrogen.

changes taking place in a mixture of straw and urine during a period of four months. Between the 60th and the 120th day little change is found to take place either in the amount of "stabilised" or "fixed" nitrogen or the proportion of this nitrogen and the ammonia which appears to be held by fermented material even at a high temperature (37°C. = 99°F.), and in spite of the frequent handling and exposure associated with sampling operations. In general, it may be stated that when straw has worked from an unsaturated to a "stable" phase little or no free ammonia is to be found, but straw which commences with a super-abundance of nitrogen appears to hold, when in a fermented state, upwards of 14 per cent. of its nitrogen in the form of ammonia so long as the material is in a moist condition. Desiccation leads almost to complete loss of ammonia, and in this respect as well as in the proportion of ammonia in the moist material, the artificial resembles the natural manure.

From the study of the inter-relations between nitrogen and straw, we have come to the conclusion that the amount of nitrogen necessary for pronounced rotting, and the amount which straw is capable of "fixing" in the form of ammonia are identical, and that, in general, the figure varies only between 0·70 and 0·75 parts of nitrogen per 100 parts of dry straw. Within these limits fermentation proceeds without loss of nitrogen, and it is obvious that, except in so far as the nitrogen content of the original straw varies, the final "stabilised" product obtained when rotting has proceeded to the extent of 40 to 45 per cent. of dry matter must likewise exhibit comparatively slight variation in its nitrogen content. In our experiments the "stabilised" product obtained from the fermentation of straw under a variety of conditions possesses a nitrogen content of about 2 per cent. calculated on the dry material.

It thus becomes possible to estimate fairly accurately what the nitrogen content of any particular sample of fermented straw will be when rotting has proceeded to an appreciable extent. If, for example, the nitrogen content of the original straw is equal to 0·50 per cent. and we assume that the theoretical amount of ammonia nitrogen, equal to 0·72 lb. of nitrogen for 100 lb. of straw, has been fixed, then, with a loss of 40 per cent. of

dry matter during fermentation, the resultant rotted straw will contain $(0\cdot50+0\cdot72)\times100\div60=2\cdot03$ per cent. of organic nitrogen in the dry matter. An additional amount of ammonia nitrogen would probably result in a portion remaining as free ammonia which, as indicated above, would be liable to loss if the fermented straw were allowed to become dry. The data thus obtained enable us to turn to the process of inducing the fermentation of straw on a large scale, and are also capable of application to the conditions operating in the production of ordinary farmyard manure.

SUGGESTED METHOD FOR THE PREPARATION OF ARTIFICIAL MANURE.*

As regards large scale work, a number of factors have to be taken into account which did not operate in the laboratory experiments. Experience has shown that urea and ammonium carbonate are the most suitable carriers of nitrogen since they ensure a favourable alkaline reaction, and lead to rapid breakdown, provided that they are not present in large excess. They are, however, far too expensive at the present time to admit of general use in farm work, although a reduction in the cost of manufacturing synthetic urea would create conditions favourable to its extended use. As an alternative source of nitrogen, cyanamide (nitrolim) and sulphate of ammonia have been used with success. Whilst cyanamide already contains sufficient free lime to keep in check any acid compounds formed during fermentation, sulphate of ammonia must be supplemented by the addition of a base, and for this purpose finely-ground chalk, ground limestone, or waste lime from causticising plant at soap works may be used. For general purposes it will be found that upwards of $\frac{3}{4}$ cwt. of sulphate of ammonia and 1 cwt. of finely divided carbonate of lime per ton of straw are sufficient to induce fermentation. The main obstacles to large scale operations at the present time arise from the great tardiness

* This process, as well as its application to the purification of sewage, has been covered by Letters Patent (British Pat. No. 152387).

with which raw straw takes up the moisture necessary for fermentation. Where pits are available this difficulty may be overcome by allowing the straw to remain immersed for 2 to 4 days, after which the free liquid may be drained off. In the case of heaps or stacks on open ground no advantage appears to be obtained by continued wetting with large quantities of water, and we suggest, as a more effective method of securing the necessary saturation of the straw, sprinkling the heap comparatively lightly with water and allowing a couple of days to elapse before a second sprinkling is given. During this time a slight fermentation with increase in temperature sets in, rendering the straw more capable of absorbing a second slight application of water than would otherwise be the case. When examination has shown that the interior of the heap has become uniformly moist, the source of nitrogen may be applied in the form of solution, or in the case of cyanamide and other products, this may be broadcasted over the surface of the heap and watered in. The most convenient method of making the heap, wetting the straw, and supplying the necessary nitrogen for fermentation depends so much on local conditions that much must be left to the initiative of the farmer himself.

General characteristics of artificial farmyard manure.

Artificial farmyard manure prepared from straw is a well disintegrated plastic material in which the tubular character of the straw has been to a great extent destroyed. There is an almost complete absence of smell, the little there is being slightly fusty or mouldy in character. When prepared through the agency of a compound in the presence of free lime, there is a tendency towards the production of a blackish colour, while if prepared from soluble alkalies such as ammonium carbonate, liquid ammonia or compounds giving free ammonia such as urea or peptone, or in the presence of sodium hydroxide or sodium carbonate, the colour is dark brown, and differs only slightly from the natural product. The liquid, which is gradually expressed from the fermenting straw as more and more dry matter is lost by fermentation, has a

dark brown colour and a smell which is indistinguishable from stale urine.

Application of results to the production of ordinary farmyard manure.

Since it has been possible to produce material identical in physical properties with well-rotted farmyard manure, differing only in chemical composition in so far as the latter contains appreciable quantities of phosphorus and potash derived from foods consumed by the animal, the possibility suggested itself that the results might be applicable to the making of ordinary farmyard manure and led to an inquiry in this direction.

Of the three constituents ordinarily present in manure—urine, fæces and straw—the fæces appears to contribute to the physical character of the product only, since manure can be produced without their presence. Moreover, definite experiments have shown that, chemically, fæcal nitrogen is to a great extent inert and is not capable of contributing to the decomposition of straw to any degree comparable with urine nitrogen. On the contrary, certain methods of feeding farm animals, and particularly of horses, sometimes lead to the production of fæces containing quantities of readily available carbohydrates, and it has been shown[1] that such fæces are capable of supporting the fixation of atmospheric nitrogen. There is every reason to suppose, therefore, that the fæcal portion of the manure heap inclines slightly in the direction of itself requiring nitrogen rather than acting as a source of nitrogen for the decomposition of straw. With the above exception of some horse fæces, the solid excrements of farm animals may be regarded as having reached a state similar to that observed above in fermented straw, *i.e.*, containing roughly 2 per cent. of nitrogen in the dry matter. This is borne out by the following mean figures which have been obtained from various sources :—

Horse fæces	(mean of 8 records)	= 2·00	per cent. N in dry matter.
Cow	,, (,, ,, 11 ,,)	= 1·88	,, ,, ,, ,,
Sheep	,, (,, ,, 7 ,,)	= 1·92	,, ,, ,, ,,
	Average of 26 records	= 1·93	,, ,, ,, ,,

[1] *Jour. Agri. Sci.*, 1917, VIII, p. 299.

We thus see that during the process of digestion, and also possibly by virtue of bacterial action in the intestinal tracts, the percentage of organized nitrogen closely agrees with the figure repeatedly found for fermented straw to which purely mineral nitrogen was supplied, and subsequently converted by a bacterial action into organized nitrogen.

Since evidence of this stabilised condition is found in the product of the fermentation of straw and urine, and also in the undigested portion of food passing through the animal, it might be expected that comparable conditions would prevail in the manure heap. Despite the fact that the manure heap usually consists of the liquid and solid excrements of different animals fed with widely different diets, together with litter of various kinds and in variable proportions, and that this mixture is allowed to mature under conditions absolutely lacking in uniformity, the majority of the available data regarding the composition of farmyard manure indicate a striking similarity in the percentage of fixed or "non-ammoniacal" nitrogen. Without giving details of the methods of feeding or the conditions under which the manure was produced, it may be sufficient to state that the mean content of fixed or organized nitrogen in manure made under controlled conditions in America, on the Continent, and in this country, proves to be 2·09 per cent. as a mean of 43 records. We are now in a position to appreciate more accurately the character of the changes which proceed during the making and storage of manure. Repeated experiments carried out during the last three decades have shown that during this process a very considerable proportion of the nitrogen originally contained in the food and litter is almost invariably lost, and this loss, which may amount to upwards of 40 or 50 per cent. of the whole, appears to fall largely, or even exclusively, on the urine nitrogen, *i.e.*, the most valuable nitrogen, since it is the most readily available constituent of the manure. To prevent or reduce this loss both chemical and physical measures have been suggested, all of which have proved either ineffective or have interfered seriously with the rotting process.

If dung-making be regarded as essentially a straw-rotting process it is possible to obtain some explanation of much of the loss which has been found to occur. We have seen that the nitrogen-fixing power of straw is strictly limited, and that any surplus nitrogen in the form of ammonia is liable to loss by evaporation. It may therefore be assumed that the practice of supplying concentrated feeding stuffs to farm livestock merely results in an increased production of soluble nitrogen, which, owing to the normally overloaded condition of the litter, is liable to relatively greater loss than where such feeding stuffs are not used.

We have attempted to test the accuracy of this view by computing the amount of nitrogen that ought under ordinary conditions to be recovered in the form of manure from any given system of feeding. For this purpose we have taken—

(*a*) the total amount of nitrogen contained in the straw used as litter ; this is apparently not in a form liable to loss ;

(*b*) the amount of indigestible or fæcal nitrogen as calculated from the digestion co-efficients of the foods consumed ;

(*c*) the amount of nitrogen which the quantity of litter employed should be theoretically capable of retaining, *i.e.*, 0·72 lb. of nitrogen per 100 lb. straw ; and

(*d*) the amount of nitrogen present as ammonia at the end of the experiment ; this quantity is extremely variable and is determined by the actual conditions, aeration, exposure, and the length of the period during which the manure is stored.

The application of this method to the actual results obtained in a number of feeding experiments shows that a fairly close approximation may be obtained.

Two instances may be given, the first relating to Professor T. B. Wood's experiment at Cambridge[1], and the second to that of

[1] *Jour. Agri. Sci.*, 1907-08, II, p. 207.

Professor Hendrick[1] on the feeding of bullocks on roots and straw. The following table gives an extract of Professor Wood's data relating to the amount of total and digestible nitrogen supplied to the respective sets of animals, and the net amount excreted after deduction of the calculated nitrogen due to the live-weight increase of the animals. As the animals were not fed with straw but were able to pick over that supplied as litter, it has been assumed that one-quarter of the whole would be consumed, and due allowance has been made for this. In the two instances, therefore, after making this deduction, 41·15 and 83·85 lb. of nitrogen were supplied to the animals, whilst only 30·9 and 46·70 lb. were recovered in the manure. The totals obtained by calculating the indigestible or fæcal nitrogen, together with that contained in the litter and the amount which this litter is theoretically capable of fixing, closely approach those obtained by actual analysis of the manure, being 33·6 as against 30·9 lb. and 46·51 as compared with 46·70 lb. in the two cases respectively.

	No cake		Cake	
	Total nitrogen	Indigest. or fæcal nitrogen	Total nitrogen	Indigest. or fæcal nitrogen
	lb.	lb.	lb.	lb.
Mangolds	17·6	4·0	17·6	4·0
Hay	21·3	8·5	21·3	8·5
Straw	9·0	1·7	8·6	1·65 (¼ taken as food)
Cake	—	—	42·8	5·56
Total nitrogen minus nitrogen in live-weight increase ..	41·15	14·2	83·85	19·71
			Calculated	
Fæcal nitrogen	—	14·2	—	19·71
Straw ,, ...	—	7·3	—	7·0
Nitrogen fixed by litter	—	10·2	—	9·8
Nitrogen found as ammonia ..	—	1·9	—	10·0
Total (Calculated)		=33·6		=46·51
Total actually found		=30·9		=46·70

[1] *North Scot. Coll. Agri. Bull.* 22, 1918.

The data referring to Professor Hendrick's experiments are contained in the table below in a somewhat condensed form. The total amount of nitrogen supplied to the animals as food amounted to 613 lb., and of this it has been calculated that 42 lb. were retained by the increase in live-weight of the animals, thus making the total amount which should have been present in the dung equal to 671 lb., whilst only 524 lb. were actually recovered as organic and ammonia nitrogen. For the calculation, we have taken the fæcal nitrogen as given by Professor Hendrick as 276 lb., the nitrogen contained in the litter as 100 lb., and the amount of nitrogen which would be fixed by the litter (equal to 146 cwt. with a dry matter content of 91 per cent.) as 107 lb. It will be seen that the sum thus obtained is 537 lb. by calculation, as against 524 lb. by analysis. It should be noted, however, that Professor Hendrick himself calls attention to the fact that the cattle used in the experiment did better than might have been expected from accepted scientific standards of digested litter, and raises the question as to whether the foods actually used were not more digestible and of higher starch value than is allowed in Kellner's tables. If this were the case, it would simply mean that the amount allowed in our calculation as indigestible or fæcal nitrogen is somewhat too high, and would consequently bring the totals of the analytical and the calculated amounts into still closer agreement.

Analytical data	lb.	*Calculated data*	lb.
Nitrogen supplied in food	=613	Indigest. (fæcal) nitrogen	=276
,, ,, ,, litter	=100	Nitrogen in litter	=100
Total nitrogen	=713	Nitrogen fixed by litter (16,352 lb. @ 91 per cent. dry matter × 0·72, *i.e.*, fixation constant)	=107
Total nitrogen recovered in dung	=524	Nitrogen as ammonia	=54
		Total calculated ..	=537

Similar calculations have been made in the case of other feeding experiments, but these two instances will probably suffice to show

that the amount of nitrogen which we found straw to be capable of fixing in the laboratory, is also most probably built up into organic form and to the same extent under ordinary farm conditions. It is, perhaps, outside the scope of this paper to suggest means by which the observed losses which occur in the making of manure may be minimised, but rational practice would appear to lie in the direction of a more liberal use of litter in order to increase the amount of ammonia that can be fixed, with the further result of a considerable increase in the dung-making capacity of a given number of stock.

SCIENCE AND CROP PRODUCTION.*

BY

E. J. RUSSELL, D.Sc., F.R.S.,

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THE beginning of much of our scientific work on crop production goes back to the year 1843, when Lawes and Gilbert set out to discover why farmyard manure is such an excellent fertilizer. Two opposing explanations were offered by the chemists of the day; the older view, coming down from the eighteenth century, was that the fertilizing value lay in the organic matter; the newer view put forward by Liebig in 1840 was that it lay in the ash constituents —the potash, phosphates, etc.,—left after the manure is burnt. Lawes and Gilbert considered that it lay in the ash constituents *plus* the nitrogen of the organic matter, and they devised a critical field experiment to decide the matter. They divided a field of wheat into plots of equal size, of which one received farmyard manure at the rate of 14 tons per acre, another received the ashes of exactly the same dressing of farmyard manure, a third received the mineral matter of the ashes *plus* some of the combined nitrogen that had been dissipated on burning, and a fourth lay unmanured. The results were very striking :—

Broadbalk wheat field, 1843.

	Grain Tons per acre	Straw Cwt. per acre
Farmyard manure	22	13
No manure	16	10
Ashes of farmyard manure	16	10
Mineral matter of ash *plus* sulphate of ammonia to supply combined nitrogen	26¼	15¾

* Abstract of a farmers' lecture of the British Association delivered at Edinburgh on September 7, 1921. Reprinted from *Nature*, dated 22nd September, 1921.

The ashes proved ineffective, but the ashes *plus* the combined nitrogen acted just as well as farmyard manure; it is therefore these that constitute the fertilizing constituents of the manure. Thus the old controversy was decided in a way not uncommon in science; neither side proved to be entirely correct, but both sides were found to have some basis of truth. Lawes and Gilbert did not rest content with this purely judicial and scientific conclusion; they saw that they could make up this effective mixture of ashes and combined nitrogen from mineral substances without using farmyard manure. Even in their day farmers were unable to obtain sufficient farmyard manure, and it was therefore a great achievement to be able to supplement the limited supplies by this mixture. A factory was set up, and the manufacture of the so-called artificial fertilizers began. Subsequent experience showed that the ash constituents are not all equally necessary; in practice only two of them, potash and phosphates, need be supplied in addition to nitrogen.

Chemists are rightly proud of artificial fertilizers, for they have proved extraordinarily successful in augmenting crop production all over the world. The demand for them is enormous, and in consequence prices have risen considerably within the last thirty years. Agricultural chemists are always looking out for new substances, and even during the war a new fertilizer, ammonium chloride, was added to the list and new plant has been erected for its manufacture. Modern manufacturing facilities are, perhaps, adequate for present demands, but it is certain that much more fertilizer could be used, and that as farming improves the demand will increase.

Progressive farmers have long passed the stage when it was necessary to demonstrate that artificial manures increase crop production; the position now is the much more difficult one of deciding how much money it is wise to spend on fertilizers. The old view was that the crop yield was proportional to the manurial dressing, *i.e.*, that the more the manure the bigger the crop. Lawes and Gilbert showed this was not altogether correct, and that the yield fell off after a certain sized dressing was reached; this

relationship is expressed by a straight line which ultimately becomes a curve. A later view set up by Mitscherlich was that the effect of the manure is proportional to the decrement from the maximum obtainable; that therefore the first dose of manure has a large effect; but the further doses have progressively less action. This relationship is expressed by a logarithmic curve. The present view is that the effect is at first small; then it increases and then decreases; this relationship is expressible by a curve resembling that for autocatalysis. The important practical consequence is that moderate dressings are more profitable than small ones, but they are also more profitable than much larger ones (Fig. 1).

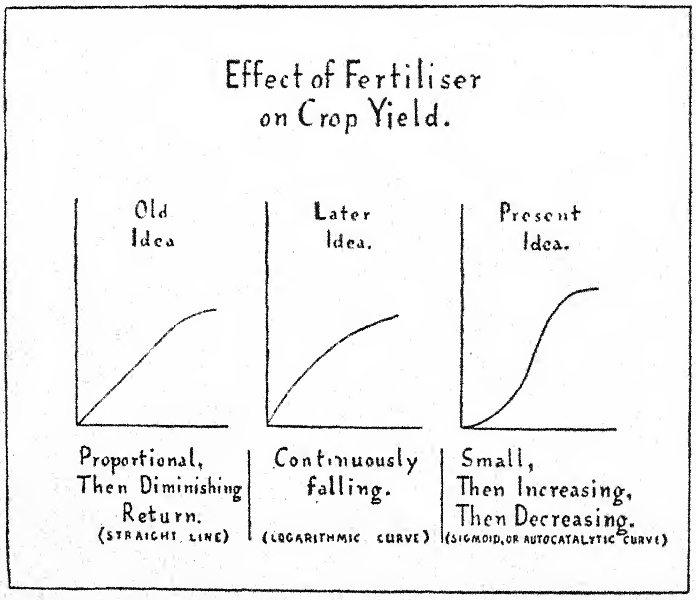

FIG. 1 Curves showing relationship between crop yield (plotted on vertical axis) and quantity of fertilizer used (plotted on horizontal axis).

There is no difficulty about the general rule; the difficulty arises when one tries to define a moderate dressing. The problem is further complicated by the fact that the effect of the dressing is

greatly influenced by the time when it is put on to the land. In our own case the results have been as follows :—

Date of application of manure	Increased yield of grain Bushels per acre			Increased yield of straw Cwt. per acre		
	Feb. 10,	March 6,	May 10	Feb. 10,	Mar. 6,	May 10
Single dressing	nil	0·9	2·7	2·7	6·9	9·4
Double dressing	7·0	—	3·7	11·7	—	12·7

This experiment ought to be repeated in many districts, for it is by no means certain that farmers generally are using the most profitable quantities of fertilizer at the most effective time. It is, however, necessary to take into account something more than the quantity and the time of application of the fertilizer. It is essential also to have a suitable mixture. In the old days this question was thought to be fairly simple. Chemists used to think that if they knew the composition of the ash of plants they would know what manure to use ; it should supply all the ash constituents in the quantities present in the plant. This is now known to be wrong ; the composition of the ash affords no guidance to manurial requirements, as was, indeed, shown by Lawes and Gilbert in 1847. The distinguished French chemist, Georges Ville, emphasized the fact that only properly conducted field trials would ever settle the question. Vast numbers of such experiments have been made, and they show that the problem is more complex than Ville thought. It is now known that no single formula expresses the fertilizer needs of a crop ; every district, almost every farm, has its own special requirements.

Still further difficulty is introduced by the fact that the various artificial fertilizers not only increase crop yields, but also influence the composition and habit of growth of the crop. Nitrogenous manures tend to a vegetative growth of large, deep-green leaves which are somewhat liable to be attacked by fungoid pests. Phosphates improve root development, and are therefore of special value for swedes and turnips ; they also hasten ripening of grain,

and are therefore particularly useful in late districts ; they increase the feeding value of crops, and are therefore useful for fodder crops ; and they have a remarkable effect on the development of clover, which is not yet fully understood, but which has revolutionized the treatment of pastures in this country. Potassic fertilizers improve the vigour of the plant and increase its power to resist fungus attacks. These and other special properties of fertilizers are now well established, and advantage is taken of them in drawing up fertilizer schemes to suit the special requirements of each farm.

It has already been pointed out that this work on artificial fertilizers arose out of Lawes and Gilbert's discovery that the wheat crop of 1843 grew just as well when supplied with the ash constituents *plus* combined nitrogen as when supplied with farmyard manure. They repeated the experiment year after year; periodically the results were collected and even after fifty years on an average the artificials had done as well as the farmyard manure. In consequence of this and other experiments many agricultural chemists developed the view that artificial manures were at least as good as farmyard manure for ordinary use on the farm ; but wider knowledge has shown that this is not the case; it is only a first approximation to say that artificial fertilizers are equally as good as farmyard manure ; we now know that farmyard manure produces effects of the highest importance to the land which no known combination of artificial fertilizers will bring about.

Examination of the Broadbalk data in the statistical laboratory recently instituted at Rothamsted under Mr. R. A. Fisher shows that farmyard manure differs in two ways from artificials—the variation in yield from year to year is diminished by the use of farmyard manure, as is also the deterioration in fertility due to continuous cropping for eighty years. No fewer than fifteen different combinations of fertilizers are tested against farmyard manure, and while some of them come out quite well on an average of twenty-five or fifty years, they fluctuate considerably from season to season, and they show manifest signs of deterioration as the years pass by. Many farmers prefer a steady yield to a fluctuating one, and this, of course, is sound, cautious business. Farmyard

manure never does badly even in the worst seasons, but, on the other hand, it does not give record crops even in the best seasons. What we should like would be something possessing the special values of farmyard manure in bad seasons, and of artificials in good ones.

Further, there is a deterioration of yield on all our plots treated with artificials excepting perhaps those receiving exceptionally high dressings. This is shown on both the wheat and the barley plots and it is greatest on those plots where one of the essential fertilizer constituents is withheld (Fig. 2).

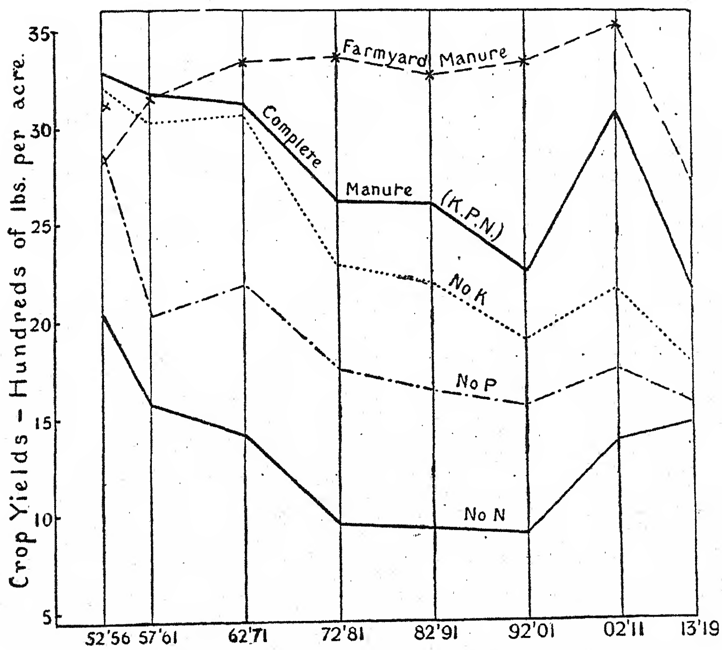

FIG. 2. Effect of fertilizers on yield of barley. (Horsfield, Rothamsted, 1852–1919.)

There is a third effect, which is very marked in rotations. Farmyard manure appears to have a greater effect than artificials in increasing the growth of clover. Unfortunately the number of experiments is not very great, but, so far as they go, they show a striking superiority over artificials, and this extends not only to the clover, but also to the succeeding wheat crop.

The results at Rothamsted are :—

Manure applied to previous corn crop	Yield of clover hay Cwt. per acre	Yield of succeeding wheat crop	
		Grain Bushels per acre	Straw Cwt. per acre
Farmyard manure	62	45	45·3
Artificials only	46	37	36·8

At present we cannot explain all these remarkable facts. There are several possibilities :—

(1) Farmyard manure is known to exercise remarkable physical effects on the soil, causing it to become puffed up so that the empty pore spaces increase in size. The air supply to the roots thus becomes better, the water supply is more evenly regulated, the work of the tillage implements is lightened, and a good tilth is more easily obtained. The difference is well shown by the root crops—swedes, turnips, and particularly mangolds, which are very sensitive to soil conditions, and being sown late, are liable to suffer from spring and summer droughts. The plots at Rothamsted receiving farmyard manure contain always some 2—5 per cent. more moisture than those receiving no manure or artificials only, and this enables the mangolds to keep growing during a drought which effectually checks all plants not receiving farmyard manure.

(2) It is possible that there are chemical constituents in farmyard manure which are not present in our artificial fertilizers. The old idea that nitrates, potash, and phosphates only are necessary may be wrong. Recent work by Maze in Paris and by Dr. Winifred Brenchley at Rothamsted show that some of the other elements may also be helpful. In the Rothamsted experiments very small quantities of boric acid added to the soil caused distinct increases in crops fully fertilized with artificial manures. We cannot as yet recommend farmers to adopt this kind of manuring with special substances, because it is very easy to overstep limits and do much damage to the crop, for the plant suffers seriously from even slight

excess. With fuller knowledge, however, it may prove possible to keep this special manuring within bounds.

(3) In the case of the clover crop the farmyard manure or the straw in the litter may have a special effect on the organisms living in the root, causing them to increase the amount of nitrogen fixation and thus give larger clover crops and further enrich the soil in nitrogenous organic matter.

Work on these problems is progressing; the scientific investigator has, of course, to find out exactly what is happening before he can show the practical man how to exercise control.

But in the meantime it is necessary for us to be practical and to do something, and the most obvious line of action is to increase the amount of farmyard manure or similar substances on the farm. We can proceed in two ways; first, wastage can be cut down. We estimate that the farmers of the United Kingdom make about forty million tons of farmyard manure a year, and waste about ten million tons. We have shown that the best results are obtained when manure is made under cover and the amount of litter properly adjusted to the amount of nitrogen in the animal excretions. Correct adjustment is a counsel of perfection, but a great improvement is possible over the present haphazard methods. In practice nitrogen is always lost through exposure to weather, greatly to the detriment of the manure. The provision of some shelter for the heap is not difficult, and, as Prof. Berry has shown at Glasgow, it is distinctly advantageous.

Another method is to increase greatly the amount of farmyard manure or similar substances produced on the farm. This could be done by running on more animals. The number of livestock per acre could be much increased by the general adoption of the methods of some of the Scottish and Danish farmers, who keep their animals largely on the produce of their arable land. The problem is closely bound up with financial considerations, but the experiments of Mr. J. C. Brown at the Harper Adams Agricultural College show that more profit is obtainable from the soiling system than from the older methods of the south.

At Rothamsted we are examining possible substitutes for farmyard manure, green-manuring, and the activated sludge method of producing manure from sewage, both of which seem quite promising. We tried using straw as manure, but without success; so soon, however, as the straw was rotted, much more promising results were obtained. The conditions for the proper rotting of straw, investigated at Rothamsted by Dr. H. B. Hutchinson and Mr. E. H. Richards, were found to be proper air and moisture supply, suitable temperature, freedom from acidity and the proper proportion of soluble nitrogen compounds. All these conditions are easily obtainable on the farm, and it is now possible to make an artificial farmyard manure from straw without the intervention of animals. So far the results seem quite satisfactory. Arrangements are being made for demonstrations on an extensive scale during the present season.

All these problems I have been discussing represent work of interest to the present generation of farmers; but the scientific investigator cannot be restricted to problems of present day interest. Some of the best work of to-day may never reach the farmer in our time, and, indeed, unless it is developed, it will never reach the farm at all. We now know that the farmyard manure and the green manure put into the soil are not really agents of fertility, but only raw materials out of which fertility is manufactured. The work is done by myriads of living creatures in the soil, which are too small to be seen by the naked eye, and only incompletely revealed even by powerful microscopes. Some of them are useful to the farmer and some not, many of them taking their toll of the valuable plant food in the soil. Their activity fluctuates daily, almost hourly, and their numbers are counted, and their work is watched in our laboratories. Much of their activity is helpful to the farmer; it makes nitrates, indispensable for the growth of plants. Much of their time, however, is spent in undoing the good work they have done, and results in the destruction of a large proportion of the nitrates made. We are studying this population, and with fuller knowledge we hope to control it and make it serve the farmer

just as horses, sheep, and cattle do; but we are a long way from that yet.

Finally an attack is being made on a much more difficult problem. The growth of a crop is like the movement of a motor car; it cannot go on without a continuous supply of energy. In the case of the car the energy comes from the petrol; in the case of the growing crop it comes from sunlight. The plant as we grow it, however, is not a very efficient transformer; a crop of wheat utilizes only about half of 1 per cent. of the energy that reaches it. During the last eighty years the growth of crops has been improved, thus increasing their efficiency as utilizers of energy; but we are still a very long way from the 30 per cent. efficiency which the motor engineer has attained. Better developments of our present methods will no doubt carry us further than we have yet gone, but some wholly fresh ideas are necessary before we can hope to bridge the enormous gap that now exists between the actual and what is theoretically possible. There seem to be at least six ways in which we might improve crop production:—

(1) We can hope for further improvements by the use of new varieties capable of making better growth than those ordinarily cultivated. Plant breeders all over the world are attacking this problem with much success, and many of the new sorts show considerable promise.

(2) Much can be done by control of plant diseases. Unfortunately we have no means of knowing how much is lost each year by pests or disease, but it is undoubtedly considerable. Laboratories for studying plant pathology have been set up at Rothamsted and elsewhere, and we are hoping to achieve good results; much valuable information has already been obtained.

(3) We are also looking to the tractor to achieve great things on the farm. It will allow considerable development of cultivation implements, enable us to improve our tillage and to keep down weeds, a very serious trouble in the southern part of England. Good Scottish farmers in that region have told me that farming in Scotland is much easier than in England, because the rigorous

northern winters keep weeds in check, while the mild southern winters encourage their growth.

(4) It is possible that certain substances, such as boric acid, the flourides, etc., studied by Gautier and Claussmann in France, may help in raising crop growth.

(5) It is possible also that special methods may prove of value, such as the high tension discharge tested by Miss Dudgeon at Lincluden, Dumfries, and ably and critically studied by Prof. V. H. Blackman.

(6) Finally, it seems probable that some wholly new method may be found for increasing crop growth. In most civilized countries there are now research institutes where the ways of plant and the properties of soils are being studied. Men of science, as a rule, do not care to risk prophecies or to attempt to create sensations, and I certainly am not going to break this wholesome rule. Something, however, has already been done; in spite of the decreased labour spent on cultivation, the yields tend to go up, while the new knowledge that is now being gained is adding greatly to the pleasure of farming and giving both masters and men an interest in their work that they never had before.

RESEARCH IN ANIMAL BREEDING.*

III.

BY

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In the previous articles of this series, published in the September and November 1921 issues of the Journal, Prof. Punnett dealt with the coat colours in cattle, and the crossing of polled with horned cattle as illustrations of simple Mendelian inheritance.

THE factorial hypothesis of heredity is, if substantiated, of fundamental importance to the breeder, for it at once raises the operations from an empirical to a scientific plane. It brings certainty where before was only conjecture. Consequently, when animal-breeding experiments were started on the University Farm at Cambridge in 1910, it was felt that among the first things to do was to choose one or two cases of apparent blending inheritance, and to study them critically in order to ascertain whether they could be interpreted on the factorial hypothesis. The choice of material was limited to small animals, for reasons of economy. This, however, was no drawback, for small animals can be bred in reasonably large numbers; and we can hardly doubt that what we learn from them is applicable to bulkier and more costly stock. Our work has, therefore, been entirely with poultry and rabbits.

One of the most extensive series of experiments undertaken with poultry was designed to investigate the inheritance of

* Reprinted from *Jour. Min. Agri.*, XXVIII, no. 3.

weight. For this purpose two standard breeds were chosen, differing markedly in size, but not so much so as to prevent natural crossing. For the larger breed we selected the Gold Pencilled Hamburgh, and for the smaller one the Silver Sebright Bantam (Plate VIII, fig. 1). As will appear later, the reason for choosing these particular breeds was to make use of the same material for the elucidation of more than one problem. From the point of view of size the two breeds differed sufficiently, for the average weights of cocks and hens respectively were for the Hamburgh about 1,400 and 1,100 grammes, while for the Sebright they were about 850 and 650 grammes. Roughly the Sebrights were about 3/5ths of the weight of the Hamburghs.

The first cross birds were intermediate in size, though approximating to the larger breed, the cockerels averaging about 1,200 grammes and the pullets about 950 grammes. From several pens of such F_1 birds, an F_2 generation of 239 birds was raised, *viz.*, 113 cockerels and 126 pullets. In contrast to the uniformity of the F_1 generation these F_2 birds exhibited a wide range of variation. As shown graphically in Fig. 1, the weights of the cockerels varied from about 550 to 1,600 grammes, while those of the pullets were from 500 to 1,200. The majority of the birds in this generation were between the weights of the original parental breeds, but a few were larger than the Hamburgh, and a few were smaller than the Sebright (Plate VIII, figs. 2 and 3). Here we have an apparent case of blended inheritance, with fair uniformity in F_1, and a wide range of variation in F_2. Can such a case be interpreted in terms of the factorial theory ? An interpretation is possible if we suppose that the Hamburgh and the Sebright differ in several factors, each of which affects the weight of the bird. The explanation of such cases was first given by Nilsson-Ehle, the well-known Swedish plant breeder, to account for the results of certain of his experiments with wheat and oats at Svalof. The closeness with which the theory fitted his results left little doubt of its being a true interpretation. The essential part of his idea is that a similar effect may be brought about by more than

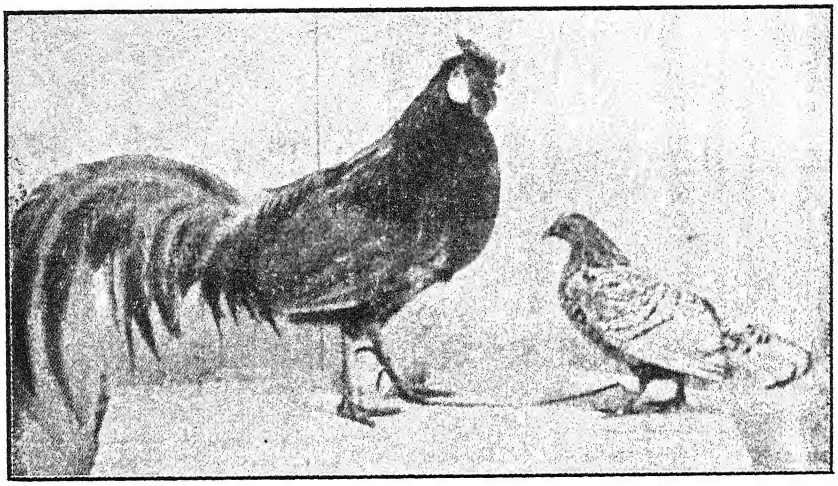

Fig. 1. Gold-pencilled Hamburgh cock and Silver Sebright hen.

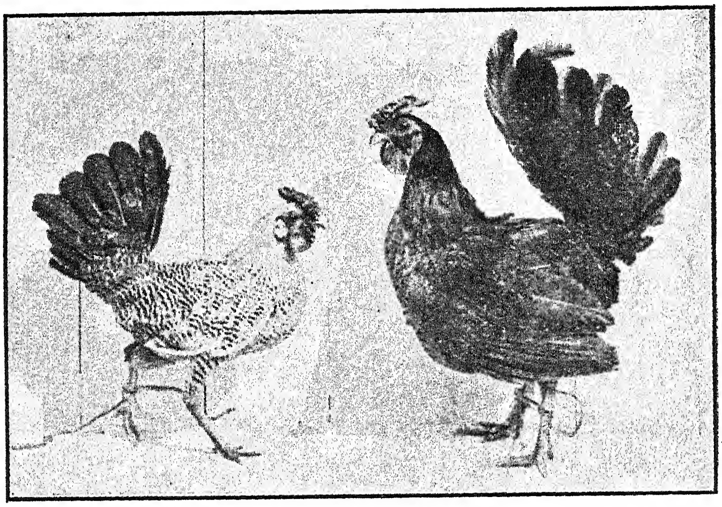

Fig. 2. Small and large F_2 cockerels.

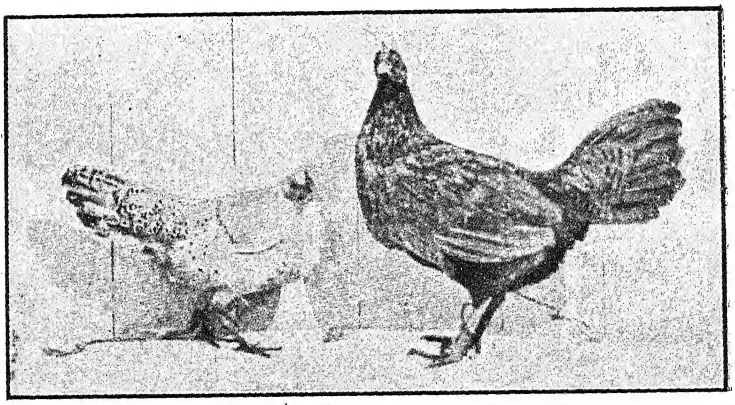

Fig. 3. Small and large F_2 pullets.

one factor, though such factors are independently transmitted in the usual way.

Let us suppose that there are several similar factors *A*, *B*, *C*, *D*, etc., which influence the weight of poultry. When a bird possesses none of these factors it will be the smallest type of bantam; when it contains *A* it will be rather larger; when it contains both *A* and *B* it will be larger again, and so on until the largest breed is reached, which must be supposed to contain a full collection of these factors. Again, let us suppose that when a bird is pure for one of these factors, *i.e.*, when it has received it from both parents, the effect on its weight is greater than when it has received it from one parent only. In other words, we suppose that dominance is not complete and that the *Aa* bird, for example, is not so heavy as the *AA* bird of otherwise similar constitution. And so also for the other weight factors *B*, *C*, *D*, etc.

Now if we suppose that the Hamburgh contained three such factors, *A*, *B* and *C*, while the Sebright contained a different one, *viz.*, *D*, we obtain a theoretical explanation which covers the observed facts :—

(1) The uniformity of the parental breeds for a markedly different average weight.

(2) The uniformity of the F_1 birds in weight.

(3) The approximation of the F_1 birds to the weight of the larger parent.

(4) The great variation in weight shown by the F_2 generation.

(5) The production in F_2 of birds larger than the Hamburgh, and of others smaller than the Sebright.

For if the Hamburgh were *AABBCCdd*, and the Sebright *aabbccDD* the F_1 birds must all be *AaBbCcDd*. They will be uniform, and at the same time, since they contain a dose each of 4 factors, they will not on our hypothesis be much lighter than birds which, like the Hamburgh, contain a double dose of 3 factors. When, however, such birds are bred together they should give an F_2 generation showing great variation, for such F_1 birds should

produce germ cells of 16 different kinds with respect to the four size factors involved, *viz.*,—

ABCD	*AbCD*	*aBCD*	*abCD*
ABCd	*AbCd*	*aBCd*	*abCd*
ABcD	*AbcD*	*aBcD*	*abcD*
ABcd	*Abcd*	*aBcd*	*abcd*

From the meeting of two such series of germ cells it is clear that all sorts of sizes will result; but the reader who wishes to follow out these possibilities in detail must be referred to the original paper.[1] It should, however, be noticed that such a combination as *AABBCCDD* will occur, in which a bird is pure for all 4 factors. Birds of this combination, as well as others such as *AABBCCDd* or *AABBCcDD*, should be heavier than the Hamburgh. Again, we may have the combination *aabbccdd* in which none of the 4 factors are found. Such birds must be smaller than the Sebright.

The theory is in accordance with the series of facts to be explained that was set out before. It can, however, be subjected to further test. The very large F_2 birds, and the very small ones should, on the theory, breed true to size. Lack of opportunity prevented the testing of the biggest ones, but a pair of the smallest F_2 birds (Plate VIII, figs. 2 and 3) was mated together, and found to breed true to the unusually small size. Lastly, among the birds of intermediate size there should be some which are pure for 2 factors, *e.g.*, *AABBccdd*, which should breed true to a size intermediate between that of the Hamburgh and the Sebright. Recent tests have revealed the existence of such birds.

This series of experiments suggests that even so complicated a character as that of weight, where inheritance is seemingly of a blended nature, can nevertheless be interpreted in terms of definite factors, each producing a definite effect. It is not of course suggested that weight is dependent solely upon such factors. Absolute uniformity, even where animals are of the same genetical

[1] "On Inheritance of Weight in Poultry," by R. C. Punnett and P. G. Bailey. *Journal of Genetics*, IV, 1914.

constitution, cannot be expected. For no two animals can be treated exactly alike with respect to food and other conditions. Moreover, it is conceivable that other factors, influencing vigour as distinct from weight, may come into operation, and produce some effect upon weight itself.

The results are not without interest in connection with the problems of in-breeding and the effects of a cross. Close in-breeding is held by some to lead to deterioration in the matter of size, and there is certainly some foundation for this belief. Yet it is by no means certain that, sometimes at any rate, this deterioration is not due to the fact that the original material was impure in some of the size factors, and that one or more of these may have been eliminated by unconscious selection. Again, there is much evidence to suggest the view that first-cross animals frequently make unusually good growth, and exceed both parental strains in weight. By some this effect is referred to the increased vigour resulting from a cross. This, of course, is no explanation, so long as we cannot state precisely how this increased vigour is brought about. It may be that there are definite factors working for vigour, though at present this has not been experimentally proved. The poultry results force us to recognize that increased size in first crosses may be due to a cumulative effect of different size factors brought in by the two parental breeds.

The two strains *AABBccdd* and *aabbCCDD* would each be of intermediate size, and nearer in this respect to the Sebright than to the Hamburgh. First-cross birds between these two would be in constitution *AaBbCcDd*, *i.e.*, of the same constitution as the F_1 Hamburgh-Sebrights. They would be larger than either of the intermediate parental strains, but this increase would not be due to vigour incidental to a cross, but to the cumulative effect of the 4 factors *A, B, C, D*, of which two were brought into the cross by each parent. Moreover, such F_1 birds might be expected to give a small proportion of progeny larger than themselves, and breeding true to this increase in size. Where a notable increase in size follows on a cross, it suggests that the breeds used contained different size factors ; and if this were so, it would be possible to establish a strain

of increased size by working on the lines indicated by the factorial theory.

Suggestive as the poultry experiments are, we recognize that we are only at the beginning of this kind of enquiry. Some experiments of a similar nature with rabbits gave a different result.[1] A cross was made between the Polish, which is the smallest of the breeds of domesticated rabbits, and the Flemish, which is one of the largest. The Polish was used as the father of the F_1 animals, which were intermediate, and fairly uniform in size (Fig. 2). From

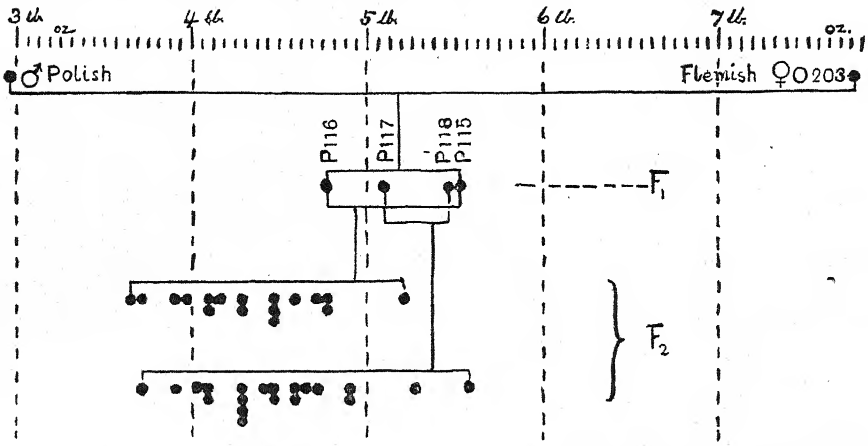

FIG. 2. Illustrating the inheritance of weight in a Polish × Flemish cross. Each individual is represented by a dot on the chart according to its weight in lb. and oz. Thus, the F_1 animal P 116 weighs 4 lb. 13 oz., and P 117 weighs 5 lb. 2 oz.

two pairs of such F_1 animals an F_2 generation was raised. Owing to lack of accommodation the total number of offspring reared was only 37. Nevertheless this F_2 generation shows a remarkable feature in that the size of the F_1 animals was not exceeded, although some were nearly as small as the Polish parent. The absence from the F_1 generation of anything approaching the size of the Flemish is highly puzzling, and no explanation can at present be offered. The experiment is being repeated with the difference that the F_1 animals have been bred from Polish doe × Flemish buck, instead of in the reverse way as before.

[1] "Genetic Studies in Rabbits, 1. On the Inheritance of Weight," by R. C. Punnett and the late P. G. Bailey. *Journal of Genetics*, VIII, 1918-19.

When planning investigations on these cases of apparently continuous variations it was felt desirable to choose another example of a different type. Accordingly a " pattern " case was selected in rabbits. Here, as in many of the domesticated animals, we encounter white markings, and the extent of these is very variable. We can in fact obtain a continuous series in the rabbit, ranging between the self-coloured animal with a touch of white on the nose or on a paw, and an animal completely white except for a touch of pigment round the eye and at the root of the tail (Plate IX, fig. 3). Such a continuous series can in fact be bred in the F_2 generation from a cross between a self-coloured animal and one of these almost white ones. The problem here again was to determine whether such an apparently continuous series could be expressed in terms of a few definite factors, or whether some other explanation had to be sought.

The case was of more than usual interest because Professor Castle, working at a similar case in rats, had put forward the view that the factor itself could be changed by " selection." Were this view upheld by experimental research it is evident that we should have to give up the conception of the relative permanence of the factor which forms the basis of the factorial theory, and with it that hope of control over breeding operations which the definite and permanent factor signifies. The results of our experiments with rabbits did not bear out Professor Castle's view. We found that a comparatively simple interpretation on factorial lines would cover the facts.[1] Moreover, Professor Castle himself has recently given up his earlier view, and considers that an orthodox explanation, in terms of the factorial theory, is adequate. We have mentioned the case here because the idea that the factor can be influenced by " selection " is to be found in text-books that are widely read. It may serve to prevent misunderstanding if it is realized that the view is no longer supported by its originator.

As we have already stated, a cross between a self-coloured animal and a " White Dutch " gives F_1 animals with a small but

[1] "The Genetics of the Dutch Rabbit—a Criticism," by R. C. Punnett. *Journal of Genetics*, IX, 1920.

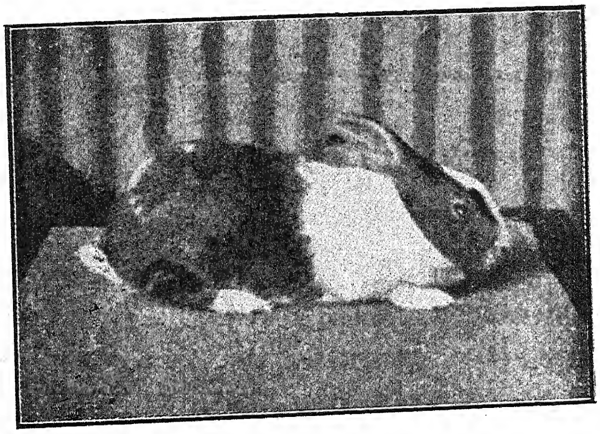

Fig. 1. Rabbit with Dutch pattern.

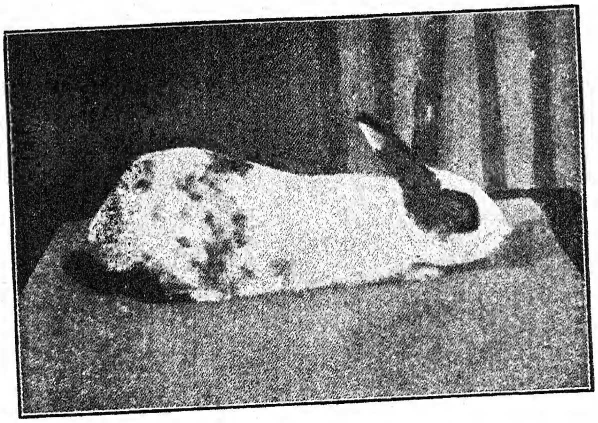

Fig. 2. Spotted Dutch rabbit.

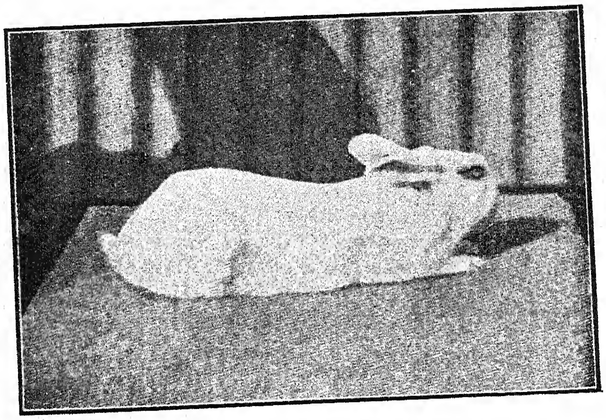

Fig. 3. White Dutch rabbit.

varying amount of white, and in F_2 a full range from Self to White Dutch. In such a series, however, the gradual increase of the White occurs in a more or less orderly fashion. It begins with the tip of the nose or muzzle, the tips of the fore-paws, and the " blaze " ; it then invades the neck, shoulders and fore-limbs ; at a more advanced stage we reach the typical pattern of the Dutch rabbit (Plate IX, fig. 1) ; later on the pigmented area round the eyes is reduced and the coloured area of the body becomes patched with white giving rise to the " spotted Dutch " (Plate IX, fig. 2) ; further reduction of the pigment eventually results in the White Dutch (Plate IX, fig. 3).

A long series of experiments has shown us that 3 pattern types corresponding to Dutch, Spotted Dutch, and White Dutch can be got to breed approximately true. The more pigmented tends to be dominant to the less pigmented, but as a rule dominance is far from complete, so that various intermediate forms arise. Two pairs of factors *T-t* and *S-s* serve to interpret the range of forms between Dutch and White Dutch, Dutch being *TTSS*, Spotted Dutch *ttSS*, and White Dutch *ttss*.

The relation of all these to the more heavily pigmented grades is determined by another factor *P* ; its presence represents much increased pigmentation. A single dose of *P* added to White Dutch transforms the animal into one with a pattern resembling the Dutch* ; added to Spotted Dutch, it leads to a grade of pigmentation between Dutch and self-colour ; added to Dutch, it results in an animal that is almost or quite self-coloured. Where the animal is *PP* the White area is further diminished, but the difference between *PP* and *Pp* animals has not yet been fully worked out.

The outstanding fact in connection with these patterns is that analysis of this continuous series, from self to almost white, has provided an interpretation in terms of the factorial theory ; and that, too, in terms of but 3 factors.

* The *Ppttss* animal may be indistinguishable from the *ppTTSS* animal in appearance but the two breed very differently.

Notes

THE POSSIBILITIES OF *RABI* CROPS IN ORISSA.

One of the problems of agriculture in Orissa is no doubt the cultivation of the flooded tracts. This problem has of late years assumed serious proportions on account of frequent failure of the paddy crop over vast areas caused by high and destructive floods. It was, therefore, decided to consider if a change of crops could not be recommended for these areas. With this view the Agricultural Department last year undertook some experiments both at the Cuttack farm and at two other typical flooded areas to test the suitability of *rabi* (winter) crops to the climatic condition of Orissa in general and to the soil condition of the flooded tracts in particular.

Of the two flooded areas where experiments were conducted, one was situated at Singapur near Jenapur where one acre and a half of land were acquired from the Raja of Madhupur for this purpose on the 29th of September, 1920. This land was previously sown with paddy which was completely destroyed by the high flood of the Brahmani which occurred in the third week of July and continued till the second week of August. As a result of the flood there was a rich deposit of coarse silt. In October the land was ploughed and cross-ploughed several times to bring it under fine tilth, and on the 1st of November the seeds were sown. All the crops were ready for the sickle within the month of March. The following table shows the crops sown, their area and yield and their yield per acre.

Serial No.	Name of crop	Area sown	Yield obtained			Yield per acre		
		Acre	Md.	Sr.	Ch.	Md.	Sr.	Ch.
1	Wheat (local)	0·1	1	22	0	15	20	0
2	Wheat (Pusa 4)	0·1	1	32	12	18	7	8
3	Barley (local)	0·16	3	0	0	18	30	0
4	Barley (Bihar)	0·1	1	30	0	17	20	0
5	Oats (Bihar)	0·1	2	15	0	23	30	0
6	Gram (Bihar)	0·1	1	23	6	15	33	12
7	Patna Pea (Bihar)	0·1	2	0	0	20	0	0
8	Lentil (Bihar)	0·1	1	7	8	11	35	0
9	Mustard (local)	0·12	0	37	0	7	28	0

From the above table it will be seen that the yield of the crops grown at Singapur can compare very favourably with the average yield of these crops in other parts of the province where they are normally cultivated. It should be mentioned that only *desi* ploughs and local bullocks were employed in preparing the land, that no manure or irrigation was given to the crops, and no weeding was necessary. The cost of cultivation, including harvesting and threshing, came to about Rs. 15 per acre.

At the Cuttack farm, in comparatively poor soil, Pusa wheat No. 4 gave an outturn of 10 maunds 30 seers per acre with two irrigations from the canal, and gram gave an outturn of 11 maunds 35 seers per acre without any irrigation or manuring.

From the above it will be seen that neither the climatic condition of Orissa nor the soil condition of the flooded tracts is unsuitable for the cultivation of *rabi* crops, and that when the paddy has failed the cultivation of these crops may be recommended without much hesitation. Of course, the soil condition of the flooded tracts is not the same everywhere. It can be divided in a general way into three classes, namely, (1) sandy, (2) loamy and (3) clayey with intermediate stages. The yield of the crop depends to a very great extent on the quality of the soil, loams being better than clays, while sandy soil is generally unsuitable. But the most important condition for the success of *rabi* crops is the conservation of moisture. Timely and thorough preparation of the land is essential and too much stress cannot be given to this point. At Singapur, in the immediate neighbourhood of our land, the cultivators had also grown local wheat. But they prepare their land indifferently,

giving it only two or three superficial ploughings, with the result that whereas we obtained a yield of $15\frac{1}{2}$ maunds per acre with well-developed, plump grain, they barely obtained a yield of 8–10 maunds per acre of immature, shrivelled grains, though we used the same seeds as they did. This difference is undoubtedly due to their bad preparation of the land and its consequent loss of moisture. Although they might have made a saving of Rs. 4 or Rs. 5 in the cost of cultivation, they lost a great deal of the profit.

Apart from the usual risks in the cultivation of *rabi* crops such as are due to changes of weather, the short and mild winters of Orissa, which though do not actually militate against the adoption of *rabi* cultivation, are factors which are likely to interfere with its success to some extent. Hence sowing should not be done until the first week of November and as far as possible early varieties of crops, such as Pusa wheat No. 4, should be selected instead of those which take longer period to mature their seeds. Also arrangements will have to be made to prevent cattle trespass which seems to be a matter of some difficulty. [S. K. BASU.]

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SHAHJAHANPUR SUGARCANE NO. 10.

IT will interest many readers of "The Agricultural Journal of India," especially sugarcane growers in the Punjab and Western U. P., to know that a variety of sugarcane, called Shahjahanpur No. 10, sent to Australia from the Shahjahanpur Sugar Experiment Station of the United Provinces, has been found to resist severe frosts remarkably well. Mr. Easterby, Superintendent of the Queensland Bureau of Sugar Experiment Stations, reports that its sugar content and keeping qualities being good it was distributed to a considerable extent in Southern Queensland. According to this officer's memorandum published in "The Australian Sugar Journal," dated the 13th September, 1921, on a recent visit to Bundaberg, his attention was directed to a very fine block of this variety, about 12 acres in extent, which had been grown at Spring Hill by the Fairymead Sugar Company under the charge of Mr. Axam. This cane was then only nine months old, but presented

a splendid vigorous growth. Mr. Axam declared that in his experience with the cane it had never been affected by frost and this was borne out by Mr. Pringle, Chemist in charge of the Bundaberg Sugar Experiment Station. If this cane maintains its reputation, it should be extremely valuable to cane growers who suffer from frost. The last analysis of the cane, made at the Bundaberg Station last year, gave the following results :—Brix, 21·7 ; Purity of juice, 91·0 ; percentage of fibre in cane, 13·6 ; commercial cane sugar, 15·05. [WYNNE SAYER.]

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MANUFACTURE OF SUGAR DIRECT FROM CANE IN INDIA.

IN view of the fact that returns supplied by Indian sugar factories are far from complete, the figures for the working season of 1919-20 published in "The Agricultural Journal of India," September 1921, have been carefully checked with the returns for the season 1920-21 with the result that certain discrepancies have been cleared up. The revised figures of the production of sugar, amount of cane crushed and the quantity of molasses turned out during the working seasons of 1919-20 and 1920-21 are given in the subjoined table. It is proposed, as the figures in returns become more complete, to revise the totals from time to time as it is found necessary.

Table showing total production of sugar by factories crushing cane. Seasons November to April, 1919-20 *and* 1920-21.

	CANE CRUSHED		SUGAR MADE		MOLASSES OBTAINED	
	1919-20	1920-21	1919-20	1920-21	1919-20	1920-21
	Mds.	Mds.	Mds.	Mds.	Mds.	Mds.
Bihar and Orissa	5,439,618	6,577,083	375,746	465,100	186,251	261,620
United Provinces of Agra and Oudh	2,140,797	2,547,871	140,241	156,777	114,504	119,231
Other Provinces of India	1,617,611	606,461	112,933	47,414	70,198	23,861
Total for India	9,198,026	9,731,415	628,920	669,291	370,953	404,712

[WYNNE SAYER.]

COMBINED MOTOR THRESHER.

We are indebted to Lieutenant J. L. Flowerdew, Officer in charge of the Military Farm, Okara, Montgomery District, Punjab, for an interesting description of work of a Combined Motor Thresher—a 24″ Bon Accord Thresher coupled with a 5 H.P. Petter Oil Engine—on a crop of wheat on that farm. The first trial, owing to the fact that the crop was harvested in accordance with the practice prevalent in that part of the country, that is, in bundles too heavy to be easily passed on to the thresher, was unsuccessful, the outturn being only about 40 maunds of grain a day. In the second trial, the bundles were broken up into small size sheaves, 7 lb. to 8 lb. each, which could be conveniently passed with hand forks on to the thresher, and the outturn was at the rate of 160 maunds of clean grain per day, equivalent to ten days' work by the country method. There was, however, no appreciable difference in the cost of the two methods.

The results are not very convincing, and a fuller trial of the thresher is therefore necessary to arrive at definite conclusions as to its suitability for adoption by zemindars of the Montgomery District. Lieutenant Flowerdew is of opinion that to suit the local requirements, the theresher should contain a bruiser for reducing straw to *bhoosa*, and that it should be constructed of structural steel instead of wood, as the latter will not stand the Indian heat without warping.

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TANKS *VERSUS* WELLS.

We have received from Mr. S. K. Gurtu, Member for Irrigation, Board of Revenue, Gwalior, the following contribution to the long standing controversy whether tanks are more suitable than wells in Central India for the development of cultivation :—

" Some people have an idea that in the long run it is cheaper to construct and work wells in Central India than storage reservoirs. This opinion is formed without collating facts and figures.

The cost of storage in Central India, on an average, is from Rs. 1,000 to Rs. 1,500 per million cubic feet. One million cubic

feet irrigate from 10 to 20 acres. We may take 15 acres as an average. Thus the capital cost of irrigating an acre is Rs. 1,500/15 = Rs. 100. The cost of constructing a well is a much more variable factor. It varies from Rs. 2,000–Rs. 10,000 according to the depth of the sub-soil water level and the nature of the substrata. In northern Gwalior the substratum is alluvial and the cost of digging is not very great, but owing to the depth of the wells, which varies from 40 to 80 feet, the cost of steining is rather high. In other portions of Gwalior like Sheopur and Isagarh and Malwa, steining is generally not required owing to the presence of rock of varying hardness in the substrata, but the item of rock blasting is a very costly one. Thus either way a deep well is an expensive affair. I have had to construct numerous wells in different localities in Central India and know that the over-all cost varies from Rs. 2,000 to Rs. 10,000. Besides, when the depth of the water is more than 60 feet below the surface, the cost of lifting it by bullock power is prohibitive and irrigation becomes impracticable. Leaving out for the present this aspect of the question, and confining ourselves to the item of capital cost alone, we may assume that an ordinary irrigation well costs about Rs. 3,000 on an average. The potential duty of a well varies from 2 to 3 acres. Assuming it to be 3 acres (the maximum) per well and taking the minimum of expenditure, the capital cost of irrigating per acre is Rs. 3,000/3 = Rs. 1,000 against Rs. 100 by flow.

"Apart from the question of capital expenditure, the working cost makes all the difference to the irrigator. In irrigating from a tank by flow, the charge for irrigation per acre to the cultivator is Rs. 3, whereas to irrigate 3 acres from a well the cultivator has to undergo the following expenses :—

	Rs.
'Charsa' (leather) which lasts a season	12
Feed of oxen for 4 months	48
Bullock driver " " "	24
Ropes and sundries	6
	90

"This gives an average figure of Rs. 90/3 = Rs. 30 per acre as cost of watering from a well against Rs. 3 per acre from tanks. This will show that, from considerations both of capital cost and recurring

expenditure, irrigation by flow is ten times cheaper than by lift from wells.

"The above assumes that every well sunk to a depth of 60 feet, on an average, will yield sufficient water. The writer's past 20 years' experience goes to show that, with the exception of wells constructed in riparian tracts, they do not yield sufficient replenishment, unless they are situated under tanks which, even if they do not fill up to brim in years of drought, keep up active percolation in the wells through sub-soil infiltration, for even when the bed of a tank is dry its substrata, from 6″ to 12″ below the bed, remain fully charged with water, and this accounts for wells below tanks not failing even in years of drought. It may be urged that as wells are more unfailing in their supplies in years of drought than tanks they should be preferred on the score of protection. This does not necessarily follow, because scarcely 1 per cent. of wells last out a summer and they almost all fail in years of drought, unless situated below tanks or near flowing drainage courses. Wells with adequate replenishment, such as will not fail even in years of drought, are few and far between.

"There is yet another factor in favour of tanks. Irrigation from tanks sets free thousands of labourers and draft cattle employed on water lifting from wells which can be more suitably employed elsewhere and leads to increase in general prosperity.

"Though tanks are cheaper and more efficient than wells, the former cannot wholly be substituted for the latter. The construction of embankments and boring of wells should go together and would be of material advantage to each other. Whenever good sites are available, we should, in the first instance, construct a tank or tanks commensurate with the requirements of the tract, followed on with wells dotted over the commanded area. In this way the cultivators will derive benefit from the combination of both, in normal and dry years.

"There are localities, notably in hilly tracts and very flat plains, where sites for tanks and reservoirs are not available. For such localities wells are clearly indicated, both for extension of cultivation and partial protection from famine—partial because the scope of

wells is rather limited. It will be seen that it is not correct to try to institute comparison between the advisability of construction of tanks or wells. One thing may be more valuable and useful than the other and yet both may be necessary. Construct tanks and construct wells, and yet more wells if you like, but exercise proper discrimination.

"The decision whether a particular tract should be protected by tanks or wells, or both, is one to be considered on its merits, into which configuration of land, nature of rainfall, surface slopes, class of soil and so many other factors enter. It is not a matter about which any one can light-heartedly dogmatise."

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ROYAL CHARTER GRANTED TO EMPIRE COTTON GROWING CORPORATION.

It is announced that the King in Council has approved the grant of a Charter to the Empire Cotton Growing Corporation. The Corporation is the permanent body which is being set up to carry into effect the recommendations made by the Empire Cotton Growing Committee. This Committee was appointed by the Board of Trade in 1917 to enquire into the possibilities of cotton production within the British Empire, in the hope that by fostering the growth of cotton in the Dominions and Colonies the industry in this country might be made less dependent upon the United States for the greater portion of its supply of raw material.

The object of the Corporation will be to extend the cotton growing areas of the Empire and thus both promote the development of the Dominions and Colonies and also assist in the stabilization of prices by drawing on a number of new areas far distant from each other, in addition to the American cotton belt, thus making the supply of raw material less dependent on climatic conditions in one part of the world. A bad season in one part of the Empire will, it is hoped, be counteracted by good crops in other British possessions, whilst Lancashire will also be enabled to view with less concern America's ever-increasing consumption of her own crop.

Under the Charter the Corporation will, amongst the other functions, have power to carry out the following work :—

(1) To assist in the enlargement and strengthening of the Agricultural Departments of the Dependencies and Colonies, and to provide facilities for training men for posts under these departments.

(2) To establish a Bureau for the dissemination of information on cotton growing, and to issue a Journal containing useful information on the subject.

(3) To undertake the marketing of crops where this will prove of assistance to the Local Governments ; this work will doubtless be done in conjunction with the British Cotton Growing Association.

As has already been announced, the Corporation will be financed by means of the grant of approximately £1,000,000 which has been made by the Government, and by a levy imposed by spinners on the raw material used in this country.

The affairs of the Corporation will be in the hands of an Administrative Council, the Presidency of which has been accepted by Lord Derby. The following gentlemen also have agreed to become the first Vice-Presidents of the Council :—Lord Ashfield, Lord Colwyn, Lord Emmott, Lord Lovat, The Rt. Hon. Sir Frederick Lugard, The Rt. Hon. Walter Runciman, Sir Frank Forbes Adam, Sir Henry Birchenough, Sir Edward Tootal Broadhurst, Sir Frank Hollins, The Hon. Sidney Peel, M.P., Mr. Thomas Shaw, M.P., and Mr. J. Arthur Hutton. [*The Board of Trade Journal*, 20th October, 1921.]

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THE YIELD OF EGYPTIAN COTTON.

In the current number of the Bulletin of the Imperial Institute (XIX, 2), Mr. Gerald C. Dudgeon, C.B.E., lately Consulting Agriculturist to the Government of Egypt, discusses the causes which have led to the decline in the yield of cotton in Egypt. Whereas during the six years ending 1899 each acre under cotton produced on

the average an annual crop of over 500 lb. of cotton, during the eight years ending 1913 the average yield had fallen to just over 400 lb., and in 1920 it was as low as 320 lb. per acre, the reduction in twenty years thus amounting to 36 per cent. Such a decline, if not checked, must in time have a serious effect on the prosperity of Egypt which depends so largely on the cotton-growing industry. It is pointed out that although the chief causes to which the decline is due have been recognized, the proportionate share of each in the result is often so unduly emphasized as to produce a misleading impression, and this is apt to lead to the adoption of incorrect procedure. In the article in question, Mr. Dudgeon places in their true perspective the different factors involved, such as the degeneration of the productive powers of the soil, the ravages of insect pests, and agrarian disturbance. He considers that great improvement would result from the completion of the comprehensive drainage scheme, which was inaugurated by the indefatigable energy of the late Lord Kitchener but was delayed by the War.

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THE FERTILIZER INDUSTRY AND NAURU PHOSPHATE.

THE manner in which the supplies of phosphate from Nauru Island will be divided among fertilizer manufacturers is evoking much interest; the companies that will be most affected are the Mount Lyell Co. in Tasmania, and the Australian Fertilizers Co. in New South Wales. Discussions are now taking place between the Electrolytic Zinc Co. of Australasia, Ltd., and superphosphate manufacturers with a view to utilizing the sulphur produced in the roasting of zinc concentrates. At present the zinc company is not working at full capacity, and its plant will not be completed for some time, but when in full operation sufficient sulphur will be available to provide for two-thirds of the superphosphate requirements of the whole of Australia, thereby rendering unnecessary the importation of sulphur from America and Japan. [*The Journal of the Society of Chemical Industry*, August 31st, 1921.]

CHANGES IN CYANAMID.

In the November (1920) issue of "The Journal of Industrial and Engineering Chemistry" there appears a paper by N. R. Harger on the changes taking place in cyanamid when mixed with fertilizer material. A great deal of research has been done on changes which take place when cyanamid alone is added to the soil or is kept in storage, but relatively little attention has been paid to changes which may occur in the material when this extremely reactive substance is mixed with the other fertilizer materials. There has been indication in some areas that mixed fertilizer containing cyanamid is somewhat toxic to plants but heretofore no experiments on the question have been reported. In the experiments under discussion the following mixtures were used : (1) acid phosphate and cyanamid ; (2) potassium sulphate, acid phosphate, and cyanamid ; (3) ammonium sulphate, acid phosphate, and cyanamid ; and (4) dried peat, acid phosphate, and cyanamid. The paper discusses the chemical changes involved and gives experimental details together with analysis, the author having devised a rapid method which is direct, for the determination of dicyanodiamide which has been found to be the substance into which cyanamid is changed under the conditions obtained. While further investigations are under way, the results which so far have been ascertained lead the author to reach the following conclusions :—

"1. When cyanamid is mixed with fertilizer materials containing acid phosphate and 5 to 10 per cent. of moisture, the cyanamid content decreases with great rapidity.

"2. This change is represented partially by, and in the higher concentrations principally by, the formation of dicyanodiamide.

"3. A given quantity of moist acid phosphate is able to transform a limited amount of calcium cyanamide.

"4. Cyanamid is not affected by dry acid phosphate.

"5. Moisture alone is able to cause the conversion of cyanamide to dicyanodiamide, but the change is much slower than when acid phosphate is present.

"Since it has been repeatedly shown that dicyanodiamide is valueless as a fertilizer material, and, moreover, is toxic to many plants, the formation of this compound in fertilizer materials seems undesirable. On first thought, it would appear that this conversion of cyanamide into dicyanodiamide could be avoided by employing dry fertilizer mixtures but this overlooks the fact that when such mixtures are added to the soil, moisture conditions are at once provided, and the transformation may possibly then take place. Preliminary experiments carried out in this laboratory indicate that, under certain conditions at least, this is the case.

"It should be noted that these unfortunate reactions between acid phosphate and cyanamid do not in any sense imply that cyanamid cannot be successfully used when mixed with other forms of phosphate. In this connection it should be noted that the Fixed Nitrogen Research Laboratory of the Ordnance Department has called our attention to the fact that lime nitrogen (cyanamid) can be mixed with calcined and basic phosphates without the excessive production of dicyanodiamide noted when moist acid phosphate is used." [*Scientific American Monthly*, III, no. 1.]

* * *

RESEARCH ON NITROGEN FIXATION.

THE sum of $500,000 has been made available for two years for the continuation of research work on fixed nitrogen. The Fixed Nitrogen Research Laboratory at American University, Washington, with a staff of 120, has been transferred from the War Department to the Department of Agriculture. [*The Journal of the Society of Chemical Industry*, August 31, 1921.]

PERSONAL NOTES, APPOINTMENTS AND TRANSFERS, MEETINGS AND CONFERENCES, ETC.

Dr. W. H. Harrison, Imperial Agricultural Chemist, has been appointed Joint Director of the Agricultural Research Institute, Pusa, from the 10th December, 1921.

***

Mr. R. C. T. Petty, who has been appointed to the Indian Agricultural Service, has been posted as Assistant Agricultural Bacteriologist in the Imperial Department of Agriculture from 19th November, 1921.

***

The appointment of Protozoologist in the Imperial Department of Agriculture, held by Dr. A. P. Jameson, is terminated from the 17th October, 1921.

***

The office attached to the appointment of Imperial Cotton Specialist in the Imperial Department of Agriculture is closed from the 9th August, 1921.

***

Dr. J. N. Sen, Supernumerary Agricultural Chemist, Pusa, was on privilege leave for three months and ten days from the 14th September, 1921.

***

Mr. J. T. Edwards, B.Sc., M.R.C.V.S., took over charge of the office of Director and First Bacteriologist, Imperial Bacteriological Laboratory, Muktesar, on the 19th November, 1921.

***

Mr. R. Cecil Wood, M.A., on return from leave, has been appointed Principal and Professor of Agriculture, Agricultural College, Coimbatore, and Superintendent, Central Farm, Coimbatore.

Mr. D. Ananda Rao, B.Sc., has been appointed Assistant to the Principal and Professor of Agriculture, Agricultural College, and Superintendent, Central Farm, Coimbatore.

***

Dr. Roland V. Norris, on return from leave, has been appointed Government Agricultural Chemist, Madras.

***

On relief by Dr. Norris, Rao Saheb M. R. Ramaswami Sivan has been appointed Government Lecturing Chemist, Madras.

***

Mr. E. Ballard, B.A., Government Entomologist, Madras, was on privilege leave for 19 days from the 1st November, 1921, Mr. T. V. Ramakrishna Ayyar holding charge.

***

Mr. D. Balakrishna Murti Garu, Mr. S. Sundararaman, M.A., F.L.S., and Mr. G. N. Rangaswami Ayyangar, B.A., of the Madras Agricultural Service, have been promoted to the Indian Agricultural Service and appointed Deputy Director of Agriculture, Government Mycologist and Millets Specialist, Madras, respectively.

***

Mr. P. C. Chaudhuri has been appointed to the Indian Agricultural Service as probationary Deputy Director of Sericulture, Bengal, from the 17th October, 1921.

***

Mr. G. G. Howard, M.R.C.V.S., D.V.H., has been appointed to the Indian Civil Veterinary Department from the 30th September, 1921, and posted to Bihar and Orissa.

***

Mr. C. P. Mayadas, M.A., B.Sc., Offg. Deputy Director of Agriculture, Western Circle, Central Provinces, whose services have been placed at the disposal of the Government of the United Provinces, has been appointed Professor of Agriculture, Agricultural College, Cawnpore.

MR. W. H. COSSAR has been appointed Second Agricultural Engineer to the Government of the United Provinces from the 1st November, 1921.

***

ON return from leave, Mr. W. Taylor resumed charge of his duties as Professor of Pathology and Bacteriology in the Punjab Veterinary College, Lahore, on the 1st October, 1921, relieving Captain K. J. S. Dowland, Professor of Parasitology, of the additional charge.

***

CAPTAIN S. G. M. HICKEY, Second Superintendent, Civil Veterinary Department, United Provinces, has been granted combined leave for nine months from the 1st November, 1921, Captain W. H. Priston, Third Superintendent, holding charge.

***

MR. S. G. MUTKEKAR, Assistant Director of Agriculture, Western Circle, is appointed to officiate as Deputy Director of Agriculture, Western Circle, Central Provinces.

***

MR. J. N. CHAKRAVARTI, Deputy Director of Agriculture, Assam, has been granted an extension of leave by two months, Srijut Laksheswar Barthakur officiating.

***

THE Ninth Meeting of the Indian Science Congress will be held in Madras from 30th January to 3rd February, 1922. His Excellency Lord Willingdon, Governor of Madras, has consented to be Patron of the meeting, and Mr. C. S. Middlemiss will be President. The following Sectional Presidents have been appointed: Agriculture, Rai Bahadur Ganga Ram; Physics and Mathematics, Mr. T. P. Bhaskara Shastri; Chemistry, Dr. N. R. Dhar; Zoology, Mr. S. W. Kemp; Botany, Dr. W. Dudgeon; Geology, Mr. G. H. Tipper; Medical Research, Major Cunningham; Anthropology, Rai Bahadur Hira Lal. Public Lectures will be delivered by Prof. Hemchandra Das Gupta, Dr. de Graaf Hunter, and Prof. J. Matthai

Reviews

Cane Sugar: A Text-book on the Agriculture of the Sugarcane, the Manufacture of Cane Sugar, and the Analysis of Sugar-house Products.—By NOEL DEERR. Second (revised and enlarged) edition. Pp. viii + 644 + 29 plates. (London: Norman Rodger.) Price, 42*s.* net.

WE welcome the revised edition just published as this book has for long been recognized as the classic compendium on all that pertains to sugar from agriculture to manufacture, and this second edition enables its author to add still further from the records of his world-wide experience in all phases of the industry to the immense amount of information contained in its pages. It is from books of this type that the general public get their real information about the industry, for it is written in a style and arranged in a way which enables the general reader when tired of chemistry to turn to plant diseases, and from manufacturing to agriculture, and still continue to absorb information about an industry whose importance is only equalled by the ramifications of its component parts. Writing, however, from the point of view of India, which is, we hope, the promised land of sugar in the future, we must confess to a feeling of disappointment that this new edition has arrived at a time when the author was just starting yet another phase of his numerous activities, and had turned his attention to the Indian sugar problem. Realizing as we do the enormous labour entailed in even revising, let alone rewriting, a book of this size, it will, we fear, be many years before we can expect to see the Indian section of the book expanded and amplified with the result of the author's work and enquiries in

India, and had it been possible to delay publication for but a year to enable much of the part dealing with India to be amplified, this would have been to the manifold advantage of the book and its legion of readers. With this one regret, and that a selfish one, we must congratulate the author on a work which displays a unique grasp of all branches of the industry it deals with. [W. S.]

***

Jute in Bengal.—By NIBARAN CHANDRA CHAUDHURY, M.R.A.S. New edition. (Calcutta: W. Newman & Co.)

THIS book might well be called a "handbook" as it is a compendium of useful information dealing with jute in all its stages. Statistics are tabulated in such a way as to make them readily available for reference, and for this purpose alone the book is valuable to all connected with the jute trade.

Part IV deals with the trade in jute and details the various stages through which the fibre passes *en route* from the producer to the consumer. The transition from the purchasers' marks to the pucca balers' marks might be dealt with at more length but it is difficult to describe unless the assorting can actually be seen.

The treatment of the fibre in the mill is not described, and if the author decides at any future date to bring out another edition he might consider the advisability of including a chapter dealing with the manufacture in the mill. It would add considerably to the interest and the value of the book.

The chapters devoted to the agricultural side of jute production are open to criticism. In the first place the author supplies us with information collected some 20 years ago and omits to refer to the work which has been done more recently. This is particularly unfortunate in the case of his chapter on manuring. No mention is made of potash, for example, which we now know to be the determining factor in the growth of the plant. In describing the fungus diseases which attack jute the author confines himself to a brief paragraph on *Diplodia*. No mention is made of *Rhizoctonia* which is a much more serious disease. "Chlorosis" in jute also receives no mention. It is very widespread throughout all the jute-growing

districts in Bengal and the total outturn must be very considerably affected by this disease.

Exception must be taken to the author's figures in his description of a 300-acre jute farm, and the man who is thereby induced to invest in a jute farm with the hopes of making a 40 per cent. profit might soon find himself disillusioned. [K. M.]

***

The Nature of Animal Light.—By E. NEWTON HARVEY. Lippincott's Monographs on Experimental Biology; pp. x+182, 35 figs., 1920. Price $ 2·50 nett.

LUMINESCENCE in animals, especially in insects, and the means by which it is brought about, have always excited the admiration of the layman and the wonder of the scientist, and it is not surprising that an enormous literature dealing with this subject has grown up. The present book is only a summary of recent views but will be of great value to anyone investigating this subject, for which India seems to offer so fertile a field for research. There is hardly any locality in India in which glow-worms are not available in quantity throughout the year, and an investigation of their luminescence should be not only of scientific interest but perhaps also of commercial utility, if it could be discovered how to reproduce light in this way on a practical scale. In this connection it may be remembered that the present methods of illumination are relatively wasteful, the efficiency of the tungsten incandescent lamp, vacuum type, for example, being given as 0·013, in comparison with the efficiency of the light of a fire-fly which is rated at 0·96. The fire-fly light, as it is, would be inefficient and trying for artificial illumination, as all objects illuminated by it would appear of a nearly uniform green hue. The most efficient light for human use, taking into account both colour and energy-light relationships, would be a light similar to that of the glow-worm containing no radiation beyond the visible spectrum, but differing from it by being white. The problem is a fascinating one and may be commended to the notice of any who are inclined to work on it in India. [T. B. F.]

NEW BOOKS

ON AGRICULTURE AND ALLIED SUBJECTS

---

1. APPLIED Entomology: An Introductory Text-book of Insects in their relations to Man, by Prof. H. T. Fernald. Pp. xiv+386. (New York and London: McGraw Hill Book Co. Inc.) Price, 21*s*. net.
2. Organic Analysis, Qualitative and Quantitative, by E. de Barry Barnett and P. C. L. Thorne. Pp. xi+168. (London: University of London Press, Ltd.) Price, 7*s*. 6*d*. net.
3. The Breeding and Feeding of Farm Stock, by James Wilson. Pp. 152. (London: Methuen & Co.) Price, 6*s*. net.
4. Crops and Tillage, by J. C. Newsham. With a Preface by Lord Bledisloe. Pp. 198. (London: Methuen & Co.) Price, 6*s*.
5. Biological Chemistry, by H. E. Roaf. Pp. 232. (London: Methuen & Co.) Price, 16*s*. 6*d*.
6. Modern Milk Goats, by I. Richards. Pp. 271. (London: J. B. Lippincott Co.) Price, 12*s*. 6*d*.
7. Common Plants, by M. Skene. Pp. 271+26 plates. (London: A. Melrose, Ltd.) Price, 6*s*. net.
8. Insect Transformation, by Prof. G. H. Carpenter. Pp. xi+282 +4 plates. (London: Methuen & Co.) Price, 12*s*. 6*d*. net.
9. How to teach Agriculture: A Book of Methods in this subject, by Ashley V. Storm and Kary C. Davis. Pp. vii+434. (London: J. B. Lippincott Co.) Price, 12*s*. 6*d*. net.

The following publications have been issued by the Imperial Department of Agriculture in India since our last issue :—

Memoirs.

1. Studies in Gujarat Cottons, Part I, by Maganlal L. Patel, B. Ag. (Botanical Series, Vol. XI, No. 4.) Price, Rs. 2 or 2*s*. 6*d*.
2. The Influence of Atmospheric Conditions upon the Germination of Indian Barley, by W. Youngman, B. Sc. (Botanical Series, Vol. XI, No. 6.) Price, As. 9 or 1*s*.
3. Variations in some Characteristics of the Fat of Buffalo and Cow Milk with changes in Season and Feeding ; The Mutual Applicability of the Analytical Figures for Butter Fat and *Ghee*, by F. J. Plymen, A.C.G.I., and A. R. Padmanabha Aiyer, B.A. (Chemical Series, Vol. VI, Nos. 4 and 5.) Price, As. 12 or 1*s*. 3*d*.

Bulletin.

4. The Bundelkhand Cottons. Experiments in their Improvement by Pure Line Selection, by B. C. Burt, M.B.E., B.Sc., and Nizamuddin Haider. (Bulletin No. 123.) Price, As. 4.

Reports.

5. Scientific Reports of the Agricultural Research Institute, Pusa (including the Report of the Imperial Dairy Expert and the Secretary, Sugar Bureau), for the year 1920-21. Price, R. 1-8.
6. Annual Report of the Imperial Bacteriological Laboratory, Muktesar, for the year ending the 31st March, 1921. Price, As. 7.

SALE OF PEDIGREE DAIRY CATTLE.

Preliminary Notice.

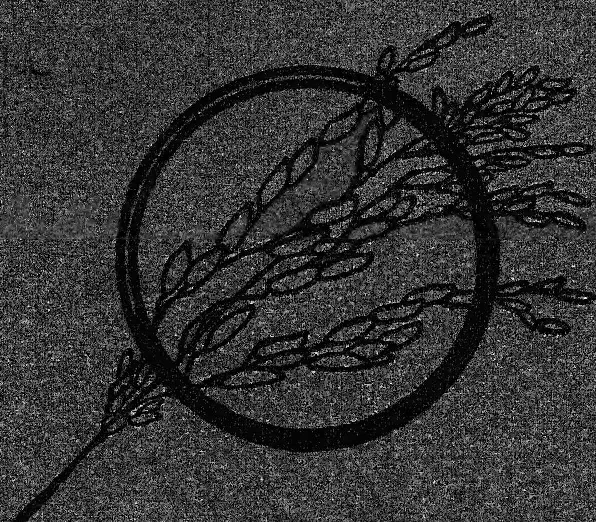
On the occasion of the next meeting of the Board of Agriculture in India, an auction sale of the surplus stock of pedigree cattle of the Pusa herd will be held at Pusa on or about the 19th February, 1922.

Particulars of the cattle available for sale can be had on application to the undersigned.

G. S. Henderson,
Imperial Agriculturist.

Pusa (Bihar).

The Agricultural Journal of India



VOL. XVII

PART II

NOTICE

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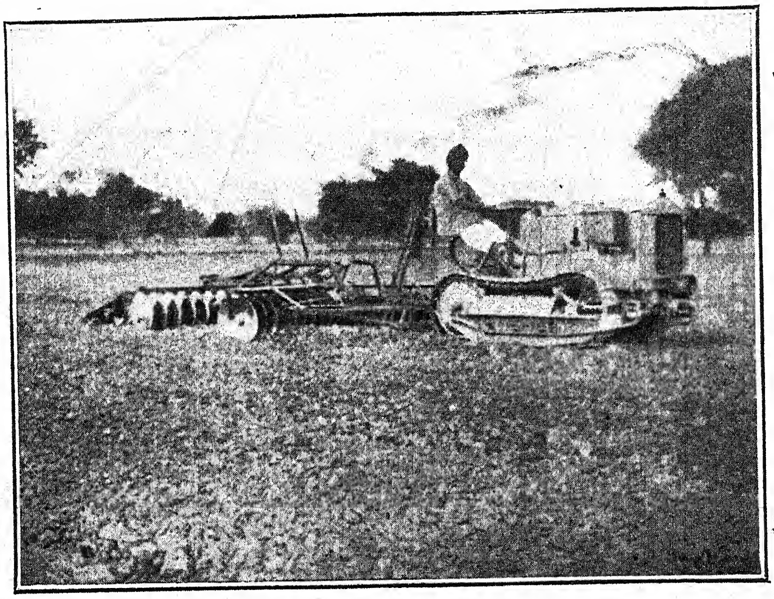
WHERE OTHERS FEAR TO TREAD



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Vol. XVII, Part II

March 1922

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NOTES ON THE NORMAL FLUCTUATIONS IN BODY WEIGHT OF BOVINES	*G. P. Goffi.*
CATTLE STOCK AND FODDER FAMINES IN HISSAR	*R. Branford, M.R.C.V.S.*
PUST-I-KUH × HASHTNAGRI SHEEP AT THE AGRICULTURAL EXPERIMENT STATION, PESHAWAR	*W. Robertson Brown.*
A METHOD OF RICE SELECTION IN ASSAM ..	*S. K. Mitra, M.Sc., Ph.D.*

THROUGH the courtesy of the British Cotton Industry Research Association the Indian Central Cotton Committee now receives a copy of the Summary of Current Literature issued weekly by the Association's Information Bureau.

The abstracts are classified under the following heads :—

(*a*) Botany, (*b*) chemistry, (*c*) colloid chemistry and physics, (*d*) physics, (*e*) cotton cultivation, (*f*) preliminary operations, (*g*) spinning, (*h*) sizing, (*i*) weaving, (*k*) bleaching, dyeing and finishing, (*l*) testing, (*m*) miscellaneous, and (*t*) additions to library.

It is proposed to reproduce any abstracts of general interest in the *Agricultural Journal of India* and the abstracts are available in the library at Bombay for the use of cotton workers.

Original Articles

SOME COMMON INDIAN BIRDS.

No. 14. THE INDIAN HOOPOE (*UPUPA EPOPS INDICA*).

BY

T. BAINBRIGGE FLETCHER, R.N., F.L.S., F.E.S., F.Z.S.,

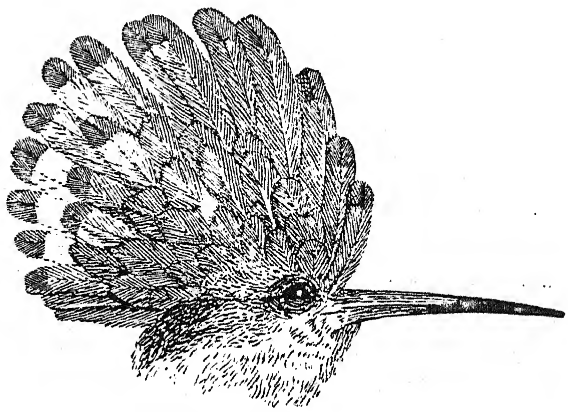
Imperial Entomologist;

AND

C. M. INGLIS, M.B.O.U., F.E.S., F.Z.S.

EXCEPT in Sind and the Western Punjab, the Indian Hoopoe is one of the most familiar of the birds which live in the Plains of India, occurring commonly, and usually abundantly as a resident in all suitable localities throughout India, Burma and Ceylon. It is a bird about the size of a mynah, fawn-coloured, the wings and tail white with very broad black bars, the legs short, the bill very long and slightly curved, and the back of the head with a conspicuous crest, which is normally kept folded so that it looks like a backward prolongation of the bill, but which is erected like an expanded fan when its owner is excited or disturbed or flies and when it first settles after flight. Specimens from South India and Ceylon run smaller than those from Northern India and have been separated under the name *Upupa ceylonensis*. Burmese specimens run larger in size, and have sometime been separated as a distinct species, *U. longirostris*, a name derived from the greater length of the bill in Burmese

examples. Besides the Indian species, the European Hoopoe (*U. epops epops*), distinguished by the presence of white between the



Head of European Hoopoe.

buff ground-colour and the black tips of the feathers of the crest on the head, is found in the Himalayas during the summer and in the winter visits the northern half of India, extending as far South as the Deccan, Chota Nagpur and Sylhet. Some Indian specimens, especially those from the North, very often show a tinge of white on the crest, and these are regarded as hybrids between the Indian and European species. In North Bihar many specimens intermediate between the Indian and European forms are to be seen. In most parts of India, however, the buff-coloured bird which is seen probing the lawn with its long bill may safely be put down as the Indian Hoopoe. A true albino with pink eyes has been recorded.

The Hoopoe is found chiefly in open country and is essentially a ground bird, only occasionally perching on trees. Its flight is slow and undulating. Like other birds which have developed a special type of bill this organ is intimately adapted to its owner's method of obtaining food, which, in the case of the Hoopoe, consists of insects and occasional worms, obtained mostly on or from under the ground, rarely on trees or in the air. The major portion of its food is obtained either by probing grassland for caterpillars living at the roots of the grasses, or by turning over leaves and rubbish for insects. It rarely picks them off plants or trees and still more rarely catches them on

the wing, although winged termites are occasionally taken in this way. The favourite haunts of this bird are avenues, especially if grass is growing in these, grasslands and lawns. It prefers slightly damp, but not wet, localities to dry ones, as its insect food is then more easily procurable. It is an interesting sight to see these birds regularly quartering a lawn, stopping every now and then to dig and probe the soil with their long beaks, the result of investigation generally yielding some insect, which is extracted and swallowed. If, however, the parent bird is collecting material to feed its young, it is often robbed by a King-crow, as we observed in our previous article on that bird.

As Mason remarks, the young birds are fed almost entirely on caterpillars (probably all cutworms), grubs of Melolonthids, and crickets, and the amount of food fed during the day to a nest of half-grown young is extraordinary. Mr. Mason watched a nest one day from 6 a.m. and in the first hour fifty-eight visits were made to the nest by the old birds, and during these visits forty-five insects were almost certainly cutworms, ten were other caterpillars and grubs (some almost certainly *Anomala* grubs) and three were crickets (one of these may have been a large beetle); during the next half-hour twenty-seven caterpillars and grubs were brought and fed to the young birds. All this food was obtained from grass lawns or under *Sissu* and mango trees. Only one insect was brought at each visit and all these insects were large ones. The same nest was watched again by Mr. Mason a week later, but the birds now seemed more wary and consequently but few of the insects fed could be identified but they appeared to be the same kinds as observed before. On the latter occasion 286 visits were paid to the nest by the parent birds between 6 a.m. and noon and about two visits per hour were made when apparently no insects were brought, so that about 274 insects were brought in and fed in six hours to the young birds, who numbered four or five at most. The food brought to the young consists practically wholly of caterpillars, beetle grubs and crickets. When bringing in food to the nest, the old bird as a rule perches near the nest to look around for danger and almost always utters a harsh

grating sound on approach to the nest and again on entering and leaving the nest.

The nesting season is in the early spring or beginning of the hot weather, and nesting takes place in any convenient hole, never at any great elevation from the ground, in trees, walls or banks. A nest has even been found on the floor of a house amongst some *bhusa* (chaff). The nest itself is a mere apology, a little hair, a few feathers, leaves or grass-stems being carelessly strewed over the floor of the hole or hollow and, when eggs are laid in a tree-hole, there is often no nest at all. These birds never remove the droppings from their nest and the stench of these is most overpowering. Four to six eggs are laid as a rule, but as many as nine are reported to have been met with occasionally. So many young are not always reared and one of these birds has been seen dropping two out of four of its young from the nest, presumably to reduce the number of mouths to feed. The egg is a very lengthened oval, pointed at one end and sometimes tending to be pointed at the other end also, not glossy, uniformly pale greyish-blue or olive-green or olive-brown or any intermediate shade, the average size being 24 by 16·5 mm. The female bird alone incubates the eggs and, especially when the eggs are near hatching, scarcely ever leaves them alone for a moment, being assiduously tended by the male bird, who brings her food continually. Mr. Inglis has seen a male bird, before the breeding season had commenced, run up to his mate and present her with an ant-lion grub. When the female bird is sitting closely in this way, she hisses like a snake if disturbed. They are very loath to leave the localities where they breed. On one occasion, to inspect a nest, the hen bird had to be pulled out of the hole and in doing so some of her tail feathers came out, but even this rather severe handling did not make her quit the place.

The young nestlings, as noted above, are fed by the parents on caterpillars and crickets and, as soon as they are able to leave the nest, they may be seen trotting after their anxious parents, making inefficient attempts at digging on their own account, but always ready to run up and have supplies thrust far down their throats by the long, curved beaks of their guardians.

It will readily be understood that a bird which feeds on insects, as does the Hoopoe, is a very useful one to the farmer. From actual examination of the stomach-contents of twenty-four birds at Pusa, the late C. W. Mason found that these had swallowed 278 insects of which the majority belonged to injurious species. A large proportion of its food also consists of cutworms and other insects living below the actual surface of the ground, so that they are fairly immune to most other enemies, and from this point of view, as a destroyer of cutworms and cockchafer grubs, the Hoopoe is most decidedly amongst the farmer's best friends and deserves every encouragement and protection. It is protected throughout the whole year, under the Wild Birds Protection Act, in Bombay, Delhi, the United Provinces, Bihar, Bengal, Assam and Burma, but in Madras in the Shevaroy Hills only. In Mysore it is not specifically protected but is presumably included in the schedule which includes all birds of bright plumage.

Both the Indian and European Hoopoes are known in Hindustani as *Hud-hud* and in Mahratti as *Sutar*. The name *Hud-hud*, as also the English name Hoopoe, are both derived from the call of these birds, a gentle "ŬK ŬK, ŬK, ŬK, ŬK," usually uttered when sitting on an exposed branch of a tree, the head being depressed until the tip of the beak almost touches the breast, the crest at the same time being laid flat down. This cry should not be confounded with the much louder deeper call of the Crow-pheasant.

Hoopoes have been kept in confinement and of course require an aviary and not a cage: the aviary should have turf laid down, as otherwise the bird's bill gets damaged whilst probing about for insects. Butler says "the best food for it consists largely of soaked ants' cocoons, supplemented by mealworms, spiders, insects of all kinds, and earthworms." They are said to get very tame in captivity.

The correct specific name of the Indian Hoopoe seems to be rather doubtful. In the third *Fauna* volume on Indian Birds, by Blanford, it is called *Upupa indica*, under which the named forms *ceylonensis*, *nigripennis* and *longirostris* are sunk, although the name *ceylonensis* has priority over *indica*, and the European Hoopoe is

separated as a distinct species under the name *U. epops*. It seems doubtful how far the Indian and European birds are really distinct and it is probably better to include them both under the name *Upupa epops*, with the names *U. epops epops* for the European race, *U. epops indica* for the North Indian race, *U. epops ceylonensis* for the South Indian and Ceylonese form, and *U. epops longirostris* for the form found in Burma.

MECHANICS OF TILLAGE IMPLEMENTS.

BY

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THE evolution of the plough has left several thousands of different patterns of that implement on the markets of the world at the present day. During last century when factories were started for the manufacture of implements on a large scale, the promotors sought out those which were the most popular in certain districts, thus forming the various standard patterns.

When several implements of one class differed slightly in minor details, the ingenious mechanic produced a further type having movable parts which could be adjusted to meet the special requirements of the various purchasers. Some of these adjustable implements find great favour among many of their users, while many other users consider them an additional burden to the troubles already connected with the implements in their possession.

The reason for this diversity of opinion is obvious. The plough must first suit the soil and be adjusted to the depth, width, and shape of the furrow it is required to make; it must be capable of adjustment to suit the particular form of power employed to pull it, and that adjustment must be effected to a nicety. If the adjustments are not perfectly accomplished then the skilful ploughman will correct these defects in his handling of the implement.

Unfortunately the days of the skilful ploughman are passing away, those days when the picked men of the districts met annually in open competition, and the work of the first prizeman excelled

only in trifling detail that of the last competitor. Skill has been largely discounted by the introduction of the wheeled plough. In this implement the wheels correct the defects caused by imperfect adjustment and the same skill is not required from the ploughman. It appears, however, to have been forgotten that a bad adjustment results in increased work for the draught animals, and, therefore, to obtain the greatest efficiency, the wheeled implement should be as carefully adjusted as its simpler prototype.

A visit to several of the leading factories for the production of agricultural implements convinces one that designers of present day soil tillage implements have not studied the mechanics of the implements from the soil tillers' point of view. Many attachments provided are "selling points" only, while other absolutely essential attachments are conspicuous by their absence, such absence being compensated for by the provision of an additional mechanical device, which necessarily adds cost to the implement, and absorbs extra power. As long as the implements continue to sell, the manufacturer is content, and the farmer has to make the best of the implement procurable. Closer co-operation between the farmer and the implement designer would probably result in simplification and improvement in many implements at present in use.

It would appear that if implement makers employed more freely designers, who, in addition to their mechanical training, possessed a thorough grasp of the practical work to be done on the land by their implements, many present day models would disappear, and the tendency would be toward lower cost and greater efficiency.

The following rough analysis of the mechanics of tillage implements may be of use to the young agriculturist in overcoming some of the difficulties often experienced in operating these implements.

In the case of a simple plough working in soil of uniform density the horizontal components of the forces acting on the mouldboard and on the landside may be taken as in equilibrium: then the resultants of the vertical plane forces comprising the

normal pressures and frictional resistance may be represented as in Fig. 1 by a and b; if to the same scale a force y, representing the

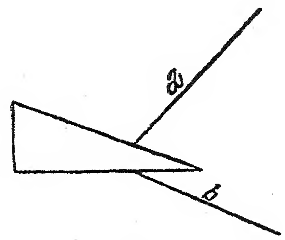

FIG. 1.

horizontal motion imparted to the implement, be drawn from g, one end of the anti-resultant R of force a and b (Fig. 2), then the

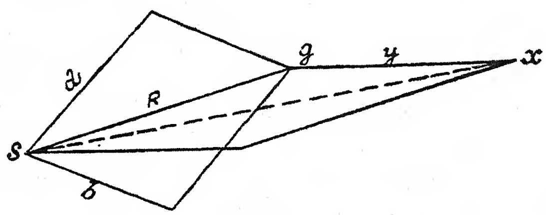

FIG. 2.

diagonal s—x of the completed parallelogram will represent, in magnitude and direction, the resultant of all forces acting on the implement.

If the total tractive force s—x (Fig. 3) be applied not in the direction s—x but in the direction s—x', then the forward motion as

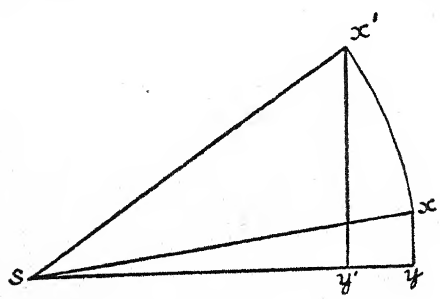

FIG. 3.

represented by s—y is reduced to s—y' and the vertical resistance as represented by y—x is increased to y'—x'. This loss of power frequently occurs in India, where, for reasons partly due to the form

of draught employed, the implement is often kept close up to the oxen, thus increasing the angle formed by the line of draught with the horizontal *x—s—y* (Fig. 3) and thereby wasting energy. The converse of this principle is exemplified in western countries where the line of draught is kept as nearly horizontal as driving facilities permit—this is known to implement makers and the implements are made in accordance with this requirement.

There is every evidence to prove that the greater part of the trouble in manipulating western implements under eastern conditions is due to the fact that these implements are primarily designed for a low draught angle and are not readily adaptable to the draught angle common in eastern countries. All forces acting on the implement, as summed in the resultant, or line of draught, must pass through the centre of resistance of the implement if the implement is to ride steadily at a uniform depth in an ideal soil of uniform density.

The centre of resistance, of a plough or any single tillage implement, is that point through which a single force must pass in order to balance or replace all forces acting on the moving implement. The centre of resistance is in the vertical line passing through the centre of gravity of the working part of the moving implement and the disturbed soil, and appears to coincide with *that* centre of gravity.

Let the point *A* (Fig. 4) represent the centre of resistance of a plough shown in the form of a triangle and *B* the draw bar or beam of the plough.

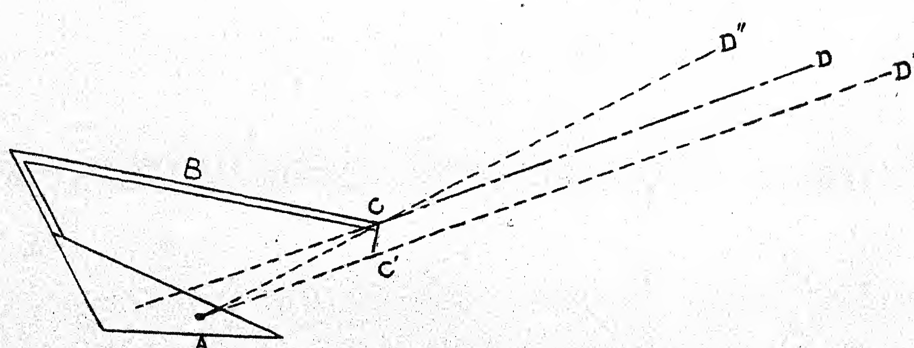

FIG.

The chain by which the implement is drawn by animal or other power is represented by the line $C—D$ attached to the beam at the point C. Now the line $D—C$ is the line of draught, and it will be observed that this line produced passes above and behind the point A. The result of this incorrect adjustment is that the point A tends to set itself in the line $D—C$ produced by its leverage, which is the perpendicular distance from point A to $D—C$ produced. With this adjustment the plough tends to dig its point into the ground, and the ploughman has to counteract this tendency by pressing on the handles.

Assuming that the angle which the line of draught makes with the horizontal is the economical angle (that is the smallest angle possible with best driving facilities), and that the height of D above ground level is a distance fixed by the type of draught animals employed, then, in order to correct the defect under these circumstances, the point of attachment C must be dropped to C' and the draught chain lengthened as shown by the line $C'—D'$. The line $D'—C'$ produced will now pass through the centre of resistance A of the implement.

A less economical method of securing the same result might be necessary if the point of attachment C was not adjustable and could not be dropped to the position C'; this could be accomplished by simply shortening the draught chain to the position $C—D''$ when $D''—C$ produced would pass through the centre of resistance A, but in this case the angle formed by $D''—C$ produced and the horizontal is no longer the economical angle and the draught animals have somewhat more work to do than necessary as exemplified by Fig. 3. Many plough makers attach a wheel to the beam in front of the plough or other implement; this wheel, by pressing on the ground surface, prevents the implement "nose diving," a tendency caused by the maladjustment shown in Fig. 4. With such ploughs the ploughman need have no trouble in pressing on the handles or in adjusting the plough, but the wheel costs money, *absorbs power*, and deprives the ploughman of that skill in plough setting which at one time was of such vital necessity. If efficiency be the keynote, then this skill is *now* of paramount importance.

In the case illustrated by Fig. 5, the line of draught as shown by *D—C* produced passes in front of the centre of resistance *A* of the

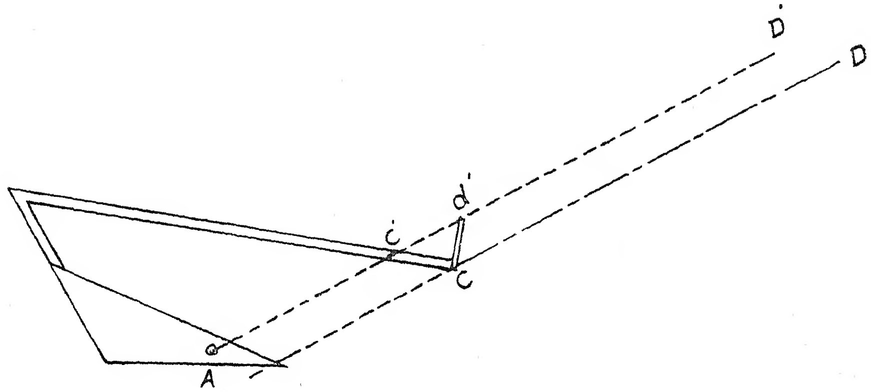

FIG. 5.

implement, the leverage being the perpendicular distance from *A* to *D—C* produced.

With this adjustment the implement will raise its point, *i.e.*, will tend to work to the surface, and the ploughman will have to exert a forward pushing force, on the handles, to counteract this tendency.

To adjust the implement correctly the draught chain would require to be attached to the beam at point *C′* or else, if a draught adjustment is fitted, the chain would be moved up to the position *d′*, the line *A—D′—d′* produced passing through the centre of resistance *A*.

When a plough is adjusted so that the line of draught passes through the centre of resistance, then the ploughman has only to correct for variations in soil density, a correction requiring only the occasional gentle touch of the skilled ploughman, man and cattle being nearly as fresh at the end of the day as when they started.

In tillage implements comprising two, three, or more tilling points, and of a type in which the points are attached to bars which are stiff in the direction of travel, such as hoes, cultivators and certain makes of harrows, etc., then the principle holds good, *viz.*, that the line of draught must pass through the centre of resistance,

if the implement is to progress with all points at a uniform depth in soil of uniform density. In implements of this class the centre of resistance is in the vertical line passing through the centre of gravity of the centres of gravity of each working part of each point and the disturbed unit of soil surrounding each point. In other words, the centre of resistance is the resultant of the centres of resistance for each point.

The ancient Egyptian and the similar present day Indian plough is provided with a long rigid draw bar or beam running the entire distance from the plough to the point of attachment at the necks of the oxen. These ploughs are locally made and generally suit the height of bullocks in the districts in which they are used. The effect of slight incorrect adjustment in a plough of this type is not so apparent as it is in a plough drawn by a flexible draught rope or chain, because *lines of stress may pass outside a rigid member without producing noticeable strain and the plough may keep its position although it and its draw bar are subjected to internal cross stresses.*

In the case of a plough or other implement drawn by a flexible draught attachment, the stress line *must pass within the flexible member* and cross stresses are an impossibility, hence the necessity for absolutely correct adjustment to secure true running of the implement.

Some modern plough makers have attempted to meet eastern requirements by attaching a rigid draw bar to a modern steel plough designed for a particular class of ploughing; it would appear impossible to produce at any central factory an implement of this type which will suit very varying heights of draught cattle in different parts of the country. In those districts where the ploughman finds difficulty in manipulating the plough, the plough is scrapped as unsuitable, the actual reason being, not because it is a bad plough, but because the line of draught does not pass through the centre of resistance, and adjustments to attain this end are not provided.

The mechanics of tillage implements is but imperfectly understood by many even of the most expert and scientific agriculturists, and naturally so, as an advanced study of kinetics

and statics is hardly part of their province. The implement makers, however, can very easily construct implements in which the line of draught will pass through the centre of resistance for average conditions, and which will have an adjustment permitting the line of draught to pass through the centre of resistance for a considerable range of conditions above and below average. A table showing positions of point of draught attachment to the "clevis," or coupling, of the implement, for different draught lengths and animal heights, would be of real benefit to the young agriculturist.

This would result in the manipulating of implements which would run level and true, without the addition of unnecessary wheels and other contraptions which are "selling points," and little better than "eye-wash" as they represent an unnecessary increase in the cost of the implement and considerable loss of energy.

It would also rapidly increase the use of modern types of implements which our agricultural authorities agree are necessary for the more efficient cultivation of the soil.

GERMINATION AND PRESERVATION OF SUGARCANE POLLEN.

BY

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GERMINATION OF SUGARCANE POLLEN.

To derive maximum benefit all pollination work involves the testing of both the pollen and the stigmas for fertility. This becomes very necessary in the case of a plant like the sugarcane, where the fertility of the sexual organs is as much an exception as the rule.

The iodine test for ascertaining the healthiness of cane pollen has been available for some time, thanks to the work of Java botanists. This, however, gives no indication as to the viability of pollen at a particular time, say, at the time of pollination, as even grains which have lost their viability stain blue with iodine. In other words, the test only indicates that the grains showing the positive reaction were viable at one time. What is required is a test for viability at the time of pollination ; and, in the experience of the writer, actual germination of the grains is the only reliable test.

Artificial culture of pollen presents difficulties of considerable magnitude owing to wide variations in the requirements of different pollens (1) as to the composition of culture media and (2) as to the optimum degrees of light and warmth for a free germination. Consequently, all attempts to germinate cane pollen in artificial culture media, made for over half a dozen years at the Cane-breeding Station, Coimbatore, proved disappointing.

Attention was, therefore, directed to growing them on live stigmas in the field, and, naturally, excellent results were obtained with sugarcane stigmas. But, as a test for viability of a particular sample of pollen, the method was found to have the following defects :—

(1) There is always the possibility of pollen from the arrow (emasculation is difficult in the cane) or other stray cane pollen (of which there is always such an abundance in the air during the cane arrowing season) getting access to the culture stigma.

(2) The germinating pollen tubes soon get lost in between the abundance of brightly coloured stigmatic hairs and are difficult to trace out.

Sowing the grains on live stigmas, other than those of sugarcane, was next tried. After an extended series of trials, comprising the testing of over 60 different species, both monocotyledons and dicotyledons, the stigmas of the following plants gave satisfactory results :—

(1) *Datura fastuosa* var. *alba*
(2) *Carica Papaya*
(3) *Hibiscus vitifolius*
(4) *Gynandropsis pentaphylla.*
(5) *Thespesia populnea.*

Ultimately, *Datura* was selected as the standard for the undermentioned reasons :—

(1) It gave the most satisfactory germination of all.

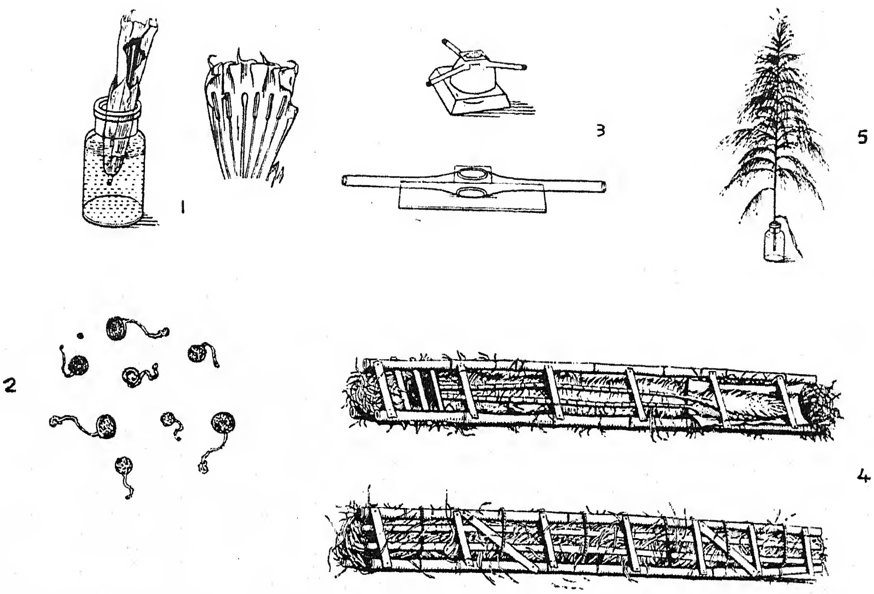
(2) The flowers are easy to emasculate and the stigmas are ready long before the anthers open.

(3) The flowers are available in quantities in the vicinity of the station during the arrowing season for canes.

(4) Stigmas remain in condition for a sufficiently long time when the bases of the flower-stalks are kept in water.

(5) *Datura* pollen could easily be distinguished from cane pollen which greatly minimizes chances of mistakes.

Details of the method of testing viability as adopted by the writer are described below.



GERMINATION AND PRESERVATION OF SUGARCANE POLLEN.

1, Flower of *Datura fastuosa* var. *alba*. *Left,* Bud with the anthers removed and ready to receive the pollen for testing; an opening in the corolla tube shows the stigma. *Right,* Corolla tube opened out to reveal the stamens and the stigma.

2, Germinating sugarcane pollen (copied from a microphotograph).

3, Improvised chambers for preserving pollen upto three hours.

4, Bamboo crates for preserving and transporting sugarcane pollen. *Above,* Arrows in position inside the crate. *Below,* Crate packed and ready for transport.

5, An arrow from the crate kept in a bottle of water to induce anther protrusion and the subsequent liberation of pollen.

Buds of *Datura*—buds which would open the same or the next evening—are collected early in the morning and kept in bottles or tubes filled with water and with the bases of the stalks dipping under it (Plate X, fig. 1). The funnel-shaped corolla is now gently opened and the anthers which would be found quite immature pulled out with a pair of pincers. The cane pollen to be tested is now dusted on the stigmas which would be found sticky and receptive. This is now kept in a cool place, preferably the shade of the cane crop, for about an hour and a half.

For examination under the microscope, a scraping is made with a mounted needle or the sharp point of a knife and mounted in plain water. If healthy, a large number of grains would be found to have germinated (Plate X, fig. 2). Very often the nucleus can be clearly made out.

Preservation of sugarcane pollen.

Pollens vary considerably as to the relative periods during which they keep viable when out of the anther sacs. Barley pollen is reported to lose viability in about ten minutes in free air.[1] In cane pollen, viability begins to decrease in about twenty minutes in open air and often disappears altogether in about half an hour.

In cross-breeding experiments the need is frequently felt to preserve pollen for a time without its losing vitality. This generally arises from a disparity between the times of flowering of the two parents. The breeding work carried on at Coimbatore aims at raising as many crosses as possible between the thin hardy Indian canes and the thick juicy canes of the Tropics. These two classes of canes flower, however, at two different periods, the bulk of the Indian canes arrowing from fifteen to twenty days later than those of the other class. The ability to preserve cane pollen in viable condition for fairly long periods is consequently of some importance to the station.

A first series of experiments showed that, when cane pollen is kept in a moist atmosphere but with free access to open air, it

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[1] Anthony and Harlan. Germination of barley pollen. *Jour. Agri. Res.*, XVIII, No. 10, Feb. 1920.

keeps viable for as many as three hours, after which it rapidly loses vitality. Two such improvised chambers are shown in Plate X, fig. 3, the humidity being kept up with water or moistened megass placed in the excavations in the slide or the slab.

With a view to extend the period of preservation, the idea was entertained of keeping the pollen within the anthers themselves by preventing their dehiscence. It was thought that these natural receptacles might prove satisfactory for preserving vitality. Previous experience with cane anthers had shown that the dryness of the atmosphere was a factor of some importance in their opening, a dewy night retarding it by as many as two to three hours. The method described below was adopted to maintain a humid atmosphere round the anthers. Arrows which were about to protrude the anthers were cut from the field together with a fair sized stalk and placed with the base of the stalk in a bottle of water (Plate X, fig. 5). This was now placed in a narrow tin or bamboo tube and covered with a lid at the top. The lid was made sufficiently loose to allow a certain amount of exchange between the air inside the tin and that outside of it. The arrows were taken out at varying periods, and it was found that, by this method. pollen could be kept viable only from six to eight hours. Beyond this period the anthers refused to protrude when taken out.

Besides preventing dehiscence, the maintenance of the vitality of the arrow as a whole was obviously indicated. After an extended series of trials the following elaborations were made with satisfactory results :—

Arrows in which the anther protrusion is commencing at the top are selected. Very early in the morning and long before the usual time for anther protrusion, the arrows are severed from the plants together with the whole stalk and a bit of the cane at the bottom to a length of one foot. The cane portion is immediately placed in a bucket of water and a fresh cut made under the water. The bucket with the arrows is now removed to a cool place, where they are taken out and the cane portions stuck into a ball of wet clay. The arrows proper now first receive a wrapping of tissue

paper and then another of brown paper; and each individual specimen, along with the stalk and the cane portion with the ball of wet clay, is gently laid inside a bamboo crate specially prepared for the purpose (Plate X, fig. 4). These crates are made a little longer than the longest of the specimens and triangular in cross section with the sides about one foot broad. The specimens are secured with twine to the crate posts at intervals, to prevent movement of the arrows when the crates are moved as a whole. Five to six arrows are thus placed inside each crate which is then wrapped round with loose straw or cane trash and tied securely round with coir rope, when it is ready for the journey. The humidity of the air inside the crate is maintained by frequent sprinkling of water over the crates. Care has, however, to be taken to see that no portion of the arrow comes in actual contact with water, as this ruins the pollen.

When pollen is required for pollination, each specimen is separately taken out, wrappings removed, portion of the stalk with the cane portion cut off and the arrow supported in a bottle of water (Plate X, fig. 5). A fairly warm room without a blow of wind is the best place to keep the arrows in. In about half an hour the anthers would be seen to come out, dehisce and liberate the pollen very much as in the field. By testing the liberated pollen for germination it has been found that pollen could thus be kept in a viable condition for as many as eleven days from the date of cutting the arrow. The arrows are to be taken out only as they are needed for pollination and about half an hour previous. Actual tests have shown that these crates could be sent in ordinary luggage vans without spoiling the vitality of the contained pollen. The actual test carried out included a railway journey over a distance of 250 miles, lasting a whole night, and a road journey in an ordinary country cart over a distance of ten miles and lasting for a period of four hours on a fairly hot day.

Summary of Results Obtained.

1. Sugarcane pollen germinates freely on the live stigmas of *Datura fastuosa* var. *alba*, thus yielding a reliable test for viability.

2. Outside the anthers and in the open air, cane pollen begins to lose viability rapidly in less than half an hour. Pollination in the sugarcane should, therefore, be done as quickly as possible after the collection of pollen.

3. A method is described by which sugarcane pollen could be preserved in a viable condition for a period of eleven days.

STUDIES ON THE DECOMPOSITION OF SOME COMMON GREEN-MANURING PLANTS AT DIFFERENT STAGES OF GROWTH IN THE BLACK COTTON SOIL OF THE CENTRAL PROVINCES.*

BY

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Introduction.

THE application of green manures to black cotton soil is an agricultural operation frequently giving rise to considerable difficulties. By black cotton soil is understood the black soil prevailing throughout a large part of the Deccan which is generally cropped with cotton, *juar* (*Andropogon Sorghum*) or some other *kharif* (monsoon) crop. Where, however, the soil is deep enough and the rainfall sufficient, wheat and other *rabi* (winter) crops can also be grown. As a rule, in the area above indicated, irrigation facilities are not available for black cotton soil, and the soil matures its *kharif* crop on the monsoon rain and its *rabi* crop on the water stored in the soil, together with whatever rain may fall during the *rabi* season. In rice-growing areas where irrigation is possible, the application of green manure and its decomposition can to a large extent be controlled as it is possible to maintain the moisture conditions of the soil at any desired state, but such facilities being generally absent in the black cotton soil tract, green-manuring in this tract is not an operation always attended with success. Black cotton soil is, however, generally so deficient in

* Paper read at the Eighth Indian Science Congress, Calcutta, 1921.

nitrogen and organic matter that green-manuring is strongly indicated, and it was considered that more detailed information on the factors governing its successful practice was required.

Experiments on the utility of green manures for *rabi* crops on the black cotton soil, especially wheat, have been carried out on the experimental farms at Nagpur and Hoshangabad since 1904 and 1909 respectively. The results of these experiments have been recorded by Allan[1] in his paper on "Green-manuring in the Central Provinces." He points out the importance of the early inversion of the green-manuring material and the intimate relationship between the rainfall subsequent to ploughing in the green manure and the yield of the following *rabi* crop. He also expressed the opinion that a minimum rainfall of 35 inches was necessary for successful green-manuring for *rabi* crops.

As regards previous work bearing on the problem dealt with in this paper, the papers by Hutchinson and Milligan[2] and by Joshi[3] may be mentioned. Hutchinson and Milligan carried out laboratory experiments on the decomposition of sann-hemp at various stages of growth and under different conditions in Pusa soil—a calcareous Gangetic alluvium of a loamy character. They considered the quantitative transformation of nitrogen alone. Joshi's work was on the comparative rate of nitrification of different green-manuring plants and different parts of the plants used as green manures in Pusa soil. He found from his experiments that the more tender and hence more easily decomposable the tissue, the slower the nitrification. This is rather contrary to general expectation; in fact, a heavy growth, leafy habit and soft non-fibrous character have been taken as indicating a plant easy of decomposition resulting in a greater nitrate accumulation. (Allan).[4] Experience in these provinces indicates that the earlier the green plants are ploughed in, the better is the succeeding *rabi* crop, but this is not quite in agreement with what

[1] *Agri. Jour. India,* X, p. 380.
[2] *Agri. Res. Inst. Pusa Bull.* 40, 1914.
[3] *Agri. Jour. India,* Special Ind. Science Congress No., 1919.
[4] *Loc. cit.*

might be expected from the results obtained in laboratory experiments with Pusa soil (Joshi)[1] where a more tender plant produced a smaller accumulation of nitrate than a woody plant. The relationship between the nature of the growth or maturity of a plant and its susceptibility to decomposition in black cotton soil has, therefore, been made subject to experiment, and this paper records the results obtained from a detailed study of the following factors connected with the process of green-manuring :—

(1) The rate of growth of plants used as green manures.
(2) The composition of the plants at various stages of growth.
(3) The rate of decomposition of the nitrogenous and carbonaceous constituents of the plants at various stages of growth and of different parts of plants, *i.e.*, leaves and stems.
(4) The effect of varying proportions of stems on the decomposition of leaves.

Experimental.

Seeds of sann-hemp (*Crotalaria juncea*) and *dhaincha* (*Sesbania aculeata*) were sown separately in duplicate pots containing black cotton soil at the beginning of the monsoon. At the end of two, four, six and twelve weeks, plants from duplicate pots of each variety were cut and used for the experiments on decomposition. With the exception of the experiments on the 12 weeks' growth of sann-hemp which were carried out in the season of 1920, all the others were carried out in 1919. The soil used for both the laboratory experiments and the pot cultures was from the Nagpur farm, and a description of its physical nature, etc., has been given by the writer[2] in one of his previous publications. It is a typical black cotton soil.

Soil representing 400 grm. of dry soil was mixed thoroughly with the required quantity of freshly cut green manure to be tested,

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[1] *Loc. cit.*
[2] *Agri. Jour. India*, Special Ind. Science Congress No., 1919.

precautions being taken to secure cut pieces of the green stuff of a uniform length of half an inch. The optimum percentage of water favouring decomposition has been found to be 30 per cent., and in order to allow for the moisture originally contained in the soil and in the green manure all of the 30 per cent. water was not added at once, but the deficiency was made up after the moisture determinations in the green manures had been made. A fixed quantity of nitrogen per 100 grm. of soil was not taken, but the amount of nitrogen added in the form of green manure was calculated afterwards when the nitrogen determinations had been carried out. Samples for moisture, ash and organic matter determinations were always taken immediately after the plants from each individual lot had been cut and while starting the nitrification and CO_2 production experiments. The remaining portions of the samples were thoroughly dried in an air oven at 100° C., ground in the sampling mill and kept in stoppered bottles for the estimations of nitrogen, carbon, etc.

Had this procedure not been adopted a good deal of time, about 10 hours at least, would have been required for the determinations of moisture and nitrogen in order to take a fixed quantity of nitrogen per 100 grm. of the soil, thus involving a great interval between the time of cutting up the green manure and mixing it with the soil, with the consequent loss of moisture. As experience of Hutchinson and Milligan[1] with sann-hemp and of Whiting and Shoonover[2] with green and cured tops of clover shows, this point of immediately mixing the cut green stuff with the soil is of very great importance.

Nitrites and nitrates were estimated by the Gries Ilosvay method and the phenol-disulphonic acid method respectively, and the amount of ammonia was estimated wherever necessary by the usual magnesia method. A detailed description of the process of these estimations has already been given.[3]

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[1] *Loc. cit.*

[2] *Soil Science*, IX, pp. 137–149.

[3] *Agri. Jour. India*, Special Ind. Science Congress No., 1919, p. 417.

In order to measure the rate of decomposition of the carbonaceous matter of the various samples, 100 or 200 grm. lots of the soil were taken, mixed with the green manure, and water added as described previously in the nitrification experiments. The difference of moisture in this case, however, was made up immediately after the first CO_2 estimation, the small quantity of water required being added by means of a graduated pippette and mixed with the soil by shaking. Erlenmeyer flasks of 500 c.c. capacity, fitted with rubber corks having two delivery tubes, one going right up to the bottom while the other one remaining nearly half the way inside the flask, were employed to hold the soil. The two ends of the delivery tubes were plugged with cotton wool in a fairly loose manner. The flasks were connected with aspirators and every day 2 litres of air freed from CO_2 was passed over the soil and into Petencoffer tubes containing standard $\frac{N}{10}$ barium hydroxide solution and phenol-phthalein. Titrations were done with $\frac{N}{10}$ hydrochloric acid. A control experiment taking the same quantity of soil and water but no green manure was also made with each series of determinations.

The relative heights and weights of the green-manuring plants of varying maturity are given in Table I and a detailed chemical

TABLE I

Showing average height in inches and average weight in grm. per plant of the respective green manures.

Green manure	2 weeks old		4 weeks old		6 weeks old		12 weeks old	
	Average height	Average weight	Average height	Average weight	Average height	Average weight	Average height	Average weight
Sann-hemp ..	15	..	24	4·05	36	7·86	50	7·0
Dhaincha ..	10	..	14	1·17	16	1·50	..	..

TABLE II

Showing the relative chemical composition of the various green-manuring plants in terms of percentages calculated on fresh green samples.

Description of the manure	Moisture	Ether extract	(a) Protein	(b) Fibre	Ash & sand	(c) Carbohydrates	N	(d) C	(e) Organic matter
1	2	3	4	5	6	7	8	9	10
Sann-hemp (2 weeks growth) ..	88·5	0·16	2·74	1·81	1·60	5·19	0·44	5·11	9·90
Dhaincha (2 weeks growth) ..	89·4	0·19	3·15	0·92	1·57	4·77	0·50	4·48	9·03
Sann-hemp (4 weeks growth) ..	82·5	0·27	2·79	5·69	1·80	6·95	0·45	7·84	15·70
Dhaincha (4 weeks growth) ..	82·6	0·47	3·18	4·68	1·62	7·46	0·51	7·95	15·78
Sann-hemp (6 weeks growth) ..	74·5	0·68	1·99	10·55	2·62	9·66	0·32	11·15	22·88
Dhaincha (6 weeks growth) ..	79·0	0·72	3·13	4·69	2·24	10·22	0·50	9·35	18·76
Sann-hemp (12 weeks growth) ..	65·0	0·47	2·01	16·56	1·90	14·06	0·32	15·86	33·10
Stems alone from sann-hemp (12 weeks growth) ..	64·0	0·38	1·44	19·30	1·33	13·55	0·23	16·13	34·67
Leaves alone from sann-hemp (12 weeks growth) ..	69·0	0·90	4·42	6·41	2·90	16·37	0·71	13·46	28·10

(a) The factor 6·25 was used for calculating the protein percentage from nitrogen.
(b) Determined by digestion with acid and alkali of 1·25 per cent. strength.
(c) By difference.
(d) By combustion.
(e) Determined by subtracting the total of columns 2 and 6 from 100.

analysis of the various samples is embodied in Table II. The figures in Table II show :—

(1) The percentage of moisture decreases as the green-manuring plants advance in age. This decrease is not, however, so great in the case of *dhaincha* as in the case of sann-hemp.

(2) The percentages of carbon, carbohydrates and fibre increase with the age of the plants.

(3) There is not an appreciable change in the percentage of nitrogen due to the increased growth of plants.

The comparative distribution of the total nitrogen in leaves and stems will be found in Table III and the relative proportion of leaves and stems in green sann-hemp 6 and 12 weeks old in Table IV.

TABLE III

Showing the distribution of the nitrogen expressed as percentage of the total nitrogen contained in sann-hemp.

	Nitrogen in leaves	Nitrogen in stems	
Sann-hemp (6 weeks growth)	55·9	44·1	11·4 top 13·7 middle 19·0 bottom
Sann-hemp (12 weeks growth)	52·1	47·9	

TABLE IV

Showing the proportion of leaves to stems in the samples of green sann-hemp in terms of percentages.

	Leaves	Stems	
Sann-hemp (6 weeks growth)	41·1	58·9	12·2 top 18·1 middle 28·6 bottom
Sann-hemp (12 weeks growth)	26·2	73·8	

These figures show that the relation between the percentages of nitrogen in leaves and in stems in the green manure under experiment varies but slightly with change in growth but that the proportion of leaves to stems is greatly reduced as the plants age.

The comparative rates of decomposition of the nitrogenous constituents as measured by the amounts of nitrites and nitrates formed in the case of sann-hemp and *dhaincha* are given in Table VI. It is seen from this table that the total percentage of nitrogen nitrified in the case of sann-hemp begins to fall as the green manure advances in age. Hutchinson and Milligan in their experiments with Pusa soil found that the maximum percentage of nitrogen nitrified after a period of 8 weeks in the case of 4, 6 and 10 weeks growth of sann-hemp was 67·8, 50 and 34·5 per cent. respectively, while the figures for black cotton soil are 57·3, 36·1 and 16·0 for 4, 6 and 12 weeks growth respectively. Their results are therefore of the same order as those described in the present paper.

TABLE V

Showing percentage nitrogen nitrified (including nitrites and nitrates) in leaves, stems, etc.

	6 WEEKS OLD SANN-HEMP				12 WEEKS OLD SANN-HEMP		
	200 grm. soil + 10 grm. leaves	200 grm. soil + 8 grm. top stems	200 grm. soil + 10 grm. middle stems	200 grm. soil + 10 grm. bottom stems	400 grm. soil + 20 grm. leaves	400 grm. soil + 20 grm. whole stems	400 grm. soil + 20 grm. leaves +20 grm. whole stems
After 2 weeks ..	..	..	..	..	15·03	nil	8·55
,, 4 ,, ..	36·88	44·66	21·97	nil	19·92	nil	16·80
,, 6 ,, ..	..	..	..	..	23·24	6·66	17·51
,, 8 ,, ..	39·37	44·66	21·97	nil	..	..	..
,, 10 ,, ..	..	..	..	..	27·20	11·10	24·60
Mg. of nitrogen added per 100 grm. soil ..	26·04	14·34	14·56	12·74	35·35	11·55	46·90

TABLE VI

Showing the total percentage nitrogen nitrified including nitrites and nitrates.

	SANN-HEMP				DHAINCHA		
	400 grm. soil + 21 grm. green manure (2 weeks growth)	400 grm. soil + 20 grm. green manure (4 weeks growth)	400 grm. soil + 20 grm. green manure (6 weeks growth)	400 grm. soil + 20 grm. green manure (12 weeks growth)	400 grm. soil + 21 grm. green manure (2 weeks growth)	400 grm. soil + 20 grm. green manure (4 weeks growth)	400 grm. soil + 20 grm. green manure (6 weeks growth)
	PERCENTAGE NITROGEN NITRIFIED						
After 2 weeks ..	56·26	36·73	24·09	1·06	43·47	45·26	46·12
„ 4 „ ..	69·60	51·58	24·09	11·96	60·41	50·33	51·24
„ 6 „ ..	78·00	51·58	32·12	13·02	62·83	55·36	61·50
„ 8 „ ..	72·39	57·31	36·14	..	60·41	62·90	..
„ 10 „ ..	..	..	..	16·00	..	..	..
Mg. of nitrogen added per 100 grm. soil ..	23·00	22·35	15·95	16·05	26·50	25·45	25·00

The following factors require consideration before attempting to correlate the gradual fall in the percentage of nitrifiable nitrogen with the advance in age of the green crop. The first consideration is the relative proportion of leaves to stems, the second, the rate of decomposition of the leaves and stems separately, and the third, the effect of varying proportions of stems on the decomposition of leaves. Results of the experiments that were made to determine factors two and three are tabulated in Table V, while Table IV, giving the relative proportion of leaves to stems, has already been referred to. With these data it is proposed now to discuss the various results.

Figures given in Table V show clearly that the nitrogen in leaves is more easily nitrifiable than that in whole stems. It is also clear that the top portions of the stems are more nitrifiable than the bottom portions.

In the case of sann-hemp 6 weeks old the percentage of nitrogen nitrified after 8 weeks is 36 per cent. (Table VI.) This represents the total oxidation of nitrogen in both leaves and various parts of stems taken together as they are present normally in a fresh sample. Now, if we calculate from the figures given in Tables III and V, the total percentage of nitrogen that should be nitrified in 8 weeks if the various parts of the plant were mixed separately with the soil, the following figures will be obtained :—

55·9 per cent. of the total nitrogen is in the leaf and 39·37 is the maximum percentage of this nitrogen nitrifiable in 8 weeks. Therefore $\frac{55 \cdot 9 \times 39 \cdot 37}{100} = 22 \cdot 00$ represents the nitrogen in the leaf which could be nitrified if 100 parts of nitrogen as contained in the whole plant were added. Similarly the top, middle and bottom parts of stems give $\frac{11 \cdot 4 \times 44 \cdot 66}{100} = 5 \cdot 09$ plus $\frac{13 \cdot 7 \times 21 \cdot 97}{100} = 2 \cdot 01$ plus $\frac{19 \times 0}{100} = 0$ of nitrogen nitrified.

The sum of these is 29·10 representing the maximum nitrifiability of 100 parts of nitrogen in the plant as a whole if all the parts are added to the soil separately. As already stated, a direct determination shows that 36 per cent. of the nitrogen in the whole plant is nitrifiable in 8 weeks.

This shows that there is no decrease in the maximum percentage of nitrogen nitrified in a sample of 6 weeks old sann-hemp when it is added as a mixture of leaves and stems to the soil, compared with the results obtained when the individual portions are added separately.

In the case of 12 weeks old sann-hemp the maximum percentage of nitrogen nitrified after a period of 10 weeks is 16·1, and if calculated on the basis of nitrification of the individual parts—leaves and stems—as in the previous case, it should be as follows :—

Leaves $\frac{52 \cdot 1 \times 27 \cdot 2}{100} = 14 \cdot 20$

Stems $\frac{47 \cdot 9 \times 11 \cdot 1}{100} = 5 \cdot 32$

Total 19·52 per cent.

Within the limits of experimental error this experiment also indicates that the stems of sann-hemp do not to any appreciable extent inhibit the nitrification of the leaves as, if this were the case, the maximum nitrification of leaves and stems separately would be appreciably higher than when the whole plant is added to the soil. Further evidence on this point was obtained by reducing the natural proportion of leaves to stems (*viz.*, 73·8 to 26·3 per cent.) to 50 per cent. of each. This was done by adding leaves and stems in equal quantities to the soil, the quantities taken being 20 grm. each of leaves and stems, to 400 grm. of soil. At the same time 20 grm. of leaves and 20 grm. of stems were added separately each to 400 grm. of soil.

The actual amount of nitrogen in 5 grm. of leaves and stems separately is 35·35 and 11·55 mg. making a total of 46·9. This quantity is that added to 100 grm. of soil. The maximum percentage of nitrogen nitrified was 27·2 in the case of leaves and 11·1 in the case of stems. Therefore the total maximum nitrifiable nitrogen added to 100 grm. of soil, when both were added together, is $\frac{35{\cdot}35 \times 27{\cdot}2}{100} + \frac{11{\cdot}55 \times 11{\cdot}1}{100} = 10{\cdot}9$ mg. 46·9 mg. of nitrogen in the mixture has, therefore, 10·9 mg. of nitrifible nitrogen or $\frac{10{\cdot}9 \times 100}{46{\cdot}9}$ or 23·24 per cent. This is the calculated figure. The actual experimental figure as in Table V is 24·6, showing that within the limits of experimental error the effect of the stem on the nitrification of nitrogen in the leaves is unappreciable. The nitrogen in the leaves or the stems appears to nitrify to the same extent in black cotton soil when the stems and leaves are mixed as when they are kept separate.

These results do not support the statement made by Joshi[1] in his paper that " it is the leaves that are nitrified in the soil, the stems and roots, if anything, inhibiting the nitrate formation or destroying the nitrates formed from leaves." If the presence of stems resulted in denitrification of the nitrates formed from leaves, then nitrites would at some stage probably be found

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[1] *Loc. cit.*

to accumulate. It may, however, be mentioned here that no extraordinary accumulation of nitrites was observed in any of these experiments in spite of the increasing amounts of stems in some of the samples.

The diminution of nitrifiable nitrogen in sann-hemp of advanced age does not therefore appear to be due to any deleterious influence of the stems upon the nitrification of leaf nitrogen. Any of the following causes may be responsible wholly or in part for reduced nitrification in the matured plant:—

(1) It is known that the fibre is more resistant to the action of micro-organisms than the other constituents of the plant, and any nitrogen contained in it would therefore be in a comparatively non-available form. Chemical determinations made in connection with this point showed that in the green sann-hemp of 12 weeks growth and in the case of stems alone from the same sample, out of the total nitrogen present about 11 and 18 per cent., respectively, was contained in the fibre. Increasing amounts of fibre in the sann-hemp as it advances in age would therefore indicate increasing amounts of nitrogen becoming more and more resistant to decomposition, thus accounting, partly at any rate, for the reduction in nitrification in the case of green manures of advanced age.

(2) It is possible that the increasing amounts of carbohydrates (Table II) in the green sann-hemp, as it advances in age, exert some deleterious influence on the nitrifiability of the nitrogenous constituents or the carbohydrates may stimulate nitrate reduction. Though it is true that this is possible in the case of solutions, it is doubtful if the same holds good in the case of soil, particularly when we consider the relatively small amount of green stuff that is added in the usual practice of green-manuring. No definite opinion on this point can however be formed at present in the case of black cotton soil but, as far as nitrate reduction is concerned, no extraordinary accumulation of nitrites was observed in any of these experiments in spite of the large amounts of carbohydrates present in some of the material under experiment.

(3) A regular decrease in the moisture content of the green manure (Table II) as it advances in age may be partly responsible

for the decrease in nitrification in the case of 6 and 12 weeks old sann-hemp. It has already been pointed out that artificial drying retards the nitrification process as seen from experiments of Hutchinson and Milligan[1] and those of A. L. Whiting and W. R. Schoonover.[2] The explanatory hypothesis given by Whiting and Schoonover in their paper is reproduced below as it seems to throw some light on this question :—

"The change which dehydration (curing) brought about in the rate of the initial decomposition (of clover) appears to be of a physical nature only. An explanatory hypothesis is that dehydration resulted in a hardening and shrivelling of tissues which interferes with the re-entrance of water and consequently delays the decomposition because the bacteria must await the softening of the tissues before they are able to start their work, while with the green no such delay occurs as the cells are already hydrated."

In the case of completely dried plants there is a maximum amount of dehydration which would exert a maximum deterrent effect, while in the case of green sann-hemp advanced in age this effect may be only partial. From the figures given in Table VII it will be seen that, in spite of the increasing percentage of carbohydrates with the advance in age of the green sann-hemp, there is a gradual reduction in the percentage of carbonaceous material decomposed, and this supports the view that, because of the altered physical condition of the various plant constituents in mature sann-hemp, decomposition by micro-organisms is not easily carried out.

In the absence of any other direct evidence it is not possible to say which of the two factors mentioned above, the formation of resistant nitrogenous substances or the hardening of the plant tissues by partial drying, is more responsible for the reduction in nitrification of mature sann-hemp.

From the results given in Tables VI and VII, it is seen that the more succulent the sann-hemp plants are, as determined from the

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[1] *Loc. cit.*

[2] *Loc. cit.*

high percentages of moisture, low percentages of fibre and shortness of period of growth, the more easily are their various constituents decomposed.

In the case of *dhaincha* there is practically no decrease in the rate of nitrification as the plants advance in growth. This can be explained if we observe the relative growth and height of the sann-hemp and *dhaincha* plants given in Table I and their compositions as given in Table II. It is seen that there was not any marked growth of the *dhaincha* plants and at the same time the range of variation in the percentages of fibre and moisture in the various stages of growth was not very great when compared with similar figures for sann-hemp.[1] The opinion was given previously that a gradual decrease in the moisture content and an increasing proportion of non-available nitrogen due to the rise in fibre content are largely responsible for the decrease in nitrification of sann-hemp plants as they advance in growth. This is further supported by the results obtained from the experiments with *dhaincha*. The fact that *dhaincha* is a slow grower in early stages as compared with sann-hemp under conditions prevailing with black cotton soil is well known and is also mentioned by Allan[1] in his paper on "Green-manuring in Central Provinces." *Dhaincha* has, however, certain advantages in resisting excessive moisture, and hence it is used as a green-manuring crop in some paddy-growing tracts and in the case of other crops where a sufficient time can be allowed for its full growth before it is turned into the soil as a green manure.

Having dealt with the decomposition of the nitrogenous constituents of plants used as green manure, we shall now consider the decomposition of the carbon constituents.

Determinations of CO_2 were made daily until the amount of CO_2 produced decreased considerably below that given off on the first day. The results of decomposition of sann-hemp as measured by the rate of CO_2 production per day are given in Table VII.

These results show a regular fall in the percentage of carbon oxidized as the age of the sann-hemp advances and are therefore

[1] *Loc. cit.*

parallel to those of nitrification but the duration of these experiments was from 15 to 20 days only. Experiments with 6 weeks old sann-hemp could not be completed but the results are given so far as available.

Potter and Snyder[1], in their experiments on the decomposition of carbon in green and dried plants, carried on their determinations for from 53 to 216 days, and found there was not any very great difference in the total percentage of carbon oxidized whether the green manure was added green or dry. Recent work by White[2] also shows only 3·3 per cent. more total organic matter oxidized when green manure is added fresh than when added dry, the determinations being continued for 9 months. The decrease in the rate of oxidation of carbon with the increase of maturity of the sann-hemp, as found by the author, may therefore be in the earlier stages of decomposition only.

From the experiments under consideration it is seen that during a period of nearly 3 weeks the decomposition of the leaves of mature sann-hemp produces twice as much carbon dioxide as that of the stems, calculated on equal weights of carbon in the leaves and stems separately. This indicates that when the plant is 12 weeks old the leaf carbon is more readily oxidized than that in the stems.

The presence of stems does not appear to affect the oxidation of leaf carbon as the following figures show :—

5 grm. leaves alone per 100 grm. soil gave off	183·1	mg. C as CO_2
5 grm. stems ,,	128·2	mg. C as CO_2
Total ..	311·3	

A mixed sample of 5 grm. leaves plus 5 grm. stems per 100 grm. soil gave off 298·1 mg. C as CO_2 or 20·16 per cent. Calculations made from the individual results of leaves and stems given above show that 21·06 per cent. of the carbon should have been oxidized,

[1] *Jour. Agri. Research*, XI, pp. 677–698.
[2] *Jour. Agri. Research*, XIII, pp. 171–197.

a difference which within the limits of experimental error cannot be said to indicate any effect of stems on the oxidation of leaf carbon.

Similar results were obtained in the case of a normal sample of green manure 12 weeks old containing 26·2 per cent. leaves and 73·8 per cent. stems. The maximum percentage of carbon that should be oxidized in a normal sample of 12 weeks old sann-hemp, if calculated from the individual figures for leaves and stems, comes to 18 per cent. whereas the percentage actually found is 21·2 per cent. As in the case of nitrogen oxidation, also the carbon in the leaves or the stems appears to oxidize to the same extent when the stems and leaves are mixed as when they are kept separate.

The rate of oxidation of carbon in *dhaincha* is given in Table VIII. These results show that there is a similar decrease in the oxidation of carbon in *dhaincha* as in the case of sann-hemp. The results for the 6 weeks old plant cannot be taken as entirely comparable as the experiments could not be carried through completely.

While these results throw some light on the quantitative rate of decomposition of the nitrogenous and carbonaceous constituents of the green-manuring plants, they also support the field experiments carried out in these provinces and summarized by Allan[1], showing that sann-hemp of about 6 weeks growth is in a condition to undergo rapid decomposition and so become of value to the succeeding *rabi* crop. The moisture factor must, however, not be overlooked.

In conclusion, I wish to express my best thanks to Mr. A.R.P. Aiyer, Offg. Agricultural Chemist, for providing some of the chemical analyses quoted in this paper.

Summary.

1. Observations on the rate of growth of sann-hemp (*Crotalaria juncea*) and *dhaincha* (*Sesbania aculeata*) in black cotton soil show that the latter is a comparatively slow grower in its initial stages.

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[1] *Loc. cit.*

2. It is seen that as the green plants advance in age the proportion of leaf to stem decreases and the percentages of dry matter and fibre increase.

3. It is seen that the earlier sann-hemp is used as green manure the more rapid is the decomposition of its carbonaceous and nitrogenous constituents. With *dhaincha*, however, there was no marked decrease in the rate of nitrification of the comparatively older plants, though there was a certain amount of decrease in the decomposition of carbonaceous constituents.

4. Nitrogen in the leaves of sann-hemp is more easily nitrified than that in stems.

5. Stems of sann-hemp do not appear to have any retarding effect on the decomposition of *sann* leaves in black cotton soil.

6. The slowness of decomposition in full-grown green *sann* plants is not due to any effect of the increasing proportion of stems on leaves. It may be due to the change in composition of the plants and such alterations which take place in the physical condition of the plant tissues owing to a large reduction in the water content. Plant tissues partially dried owing to advance in age require time to absorb water from the soil and thus become susceptible to attack by soil micro-organisms.

TABLE

Showing the amount of CO_2 evolved on successive days

	Mg. CO_2 evolved per 100 grm. of soil									
2 weeks growth	16·06	31·13	39·16	48·73	46·97	29·81	14·52	10·78	6·82	6·93
4 weeks growth	16·94	28·38	32·56	93·06	47·96	40·26	30·80	17·60	9·90	9·02
6 weeks growth	17·16	28·82	38·50	55·22	58·08	57·86	88·88	47·30	38·94	51·92
12 weeks growth	19·36	30·14	40·26	35·20	36·30	38·28	40·26	45·10	40·26	41·80
Leaves alone from 12 weeks growth	43·12	56·98	68·20	72·60	75·24	73·04	58·96	44·22	34·54	33·00
Stems alone from 12 weeks growth	14·96	18·04	17·16	18·26	25·74	29·48	48·18	48·40	46·42	37·40
Leaves and stems from 12 weeks growth in equal proportions ..	38·06	59·62	62·92	73·04	81·62	87·34	86·68	90·20	88·66	79·64

TABLE

Showing the amount of CO_2 evolved on successive days and the

	Mg. CO_2 evolved per 100 grm. of soil							
2 weeks growth, 100 grm. soil, 4 grm. green manure	17·71	36·74	38·83	41·14	35·53	23·10	10·56	7·92
4 weeks growth, 100 grm. soil, 4 grm. green manure	16·50	32·78	42·46	92·40	40·48	26·18	22·00	14·30
6 weeks growth, 100 grm. soil, 5 grm. green manure	17·16	30·36	40·04	47·30	44·88	44·66	75·02	36·30

VII

and the percentage of carbon oxidized in sann-hemp.

each successive day										Total amount of CO_2 given off in mg.		Total amount of carbon added as green manure in mg.	Total per-centage carbon oxi-dized
										As CO_2	As C		
15·73	6·82	5·39	4·40	3·63	3·85	4·84	..	..	..	295·57	80·8	204·4	39·60
7·70	7·92	11·88	6·88	3·74	3·08	..	..	..	..	367·62	100·2	313·6	31·96
..	..	..	..	..	..	..	..	..	..	482·68	131·6	557·5	23·60
41·80	28·16	27·28	35·42	39·38	36·96	18·70	11·22	11·44	..	617·32	168·4	793·0	21·24
24·86	14·96	12·10	11·44	10·12	12·76	10·34	6·82	8·14	..	671·44	183·1	673·0	27·20
31·90	22·66	22·00	19·80	18·92	21·56	12·54	7·92	8·58	..	469·92	128·2	806·5	15·90
66·88	48·18	41·58	32·56	29·48	34·76	27·94	22·88	25·96	15·18	1093·18	298·1	1479·0	20·16

VIII

percentage of carbon oxidized in dhaincha.

each successive day									Total amount of CO_2 given off in mg.		Total amount of carbon added as green manure in mg.	Total per-centage carbon oxi-dized
									As CO_2	As C		
6·27	6·05	15·40	5·08	4·18	3·85	2·86	3·63	5·61	264·46	72·20	179·20	40·30
8·36	8·80	8·36	8·80	14·08	8·14	3·96	3·30	..	350·90	95·70	318·00	30·10
31·24	54·12	..	..	..	..	..	..	..	421·08	115·00	467·50	24·60

A DISEASED CONDITION OF RICE.

BY

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Second Imperial Mycologist.

A RECENT publication[1] from the United States describes a diseased condition of irrigated rice which resembles that which has sometimes been observed in India in specimens submitted for mycological examination. The disease is named "straighthead" of rice and is stated to be one of the most destructive diseases of irrigated rice in the southern part of the United States. The chief symptom, from which the name is derived, is that the riceheads, or panicles, are nearly sterile and remain erect when mature. In severe cases plants even fail to head. All parts of the plants, however, may be affected. The leaves are said to be greener and somewhat stiffer than normal, and diseased plants remain green long after normal plants are mature and dead. There is an abundance of large roots, but few small roots and root hairs are developed.

The disease is said to be caused by certain unfavourable soil conditions, all attempts to find a parasitic organism having failed. The unfavourable condition of the soil is attributed to decaying organic matter, which produces a condition that allows an excess of water to be taken into the soil. The air is thus pressed out of the soil and, in the resulting lack of aeration, the root system fails to develop normally, disturbing the nutrition of the plant and causing the formation of empty grains. Hence the plants remain sterile and straighthead is the result. Straighthead is therefore attributed

[1] Straighthead of Rice and its Control. *U. S. A. Dept. Agri. Farmers' Bull.* 1212.

to lack of aeration in the soil and is said to be prevented by a proper system of irrigation and drainage, recommendations which have recently been advanced as a cure for " wilt " of indigo in Bihar.

The explanation of straighthead which is advanced in the paper under review is a purely physical one. If we admit that lack of soil aeration is the cause of straighthead, it is by no means improbable that the deficit of oxygen is due to more complex causes than are suggested. The presence of decaying organic matter would at least suggest that bacterial activity may result in the production of toxins, and that the benefits of aeration are due rather to the oxidation of these toxins than to the direct supply of oxygen to the plant. In paddy growing in swamp soils it has been shown that the action of an algal growth on the surface, combined with a slow downward percolation of water, results ultimately in an increase of root aeration. The downward percolation of water is a necessary condition for the health of the crop. The fact that in some parts of India large quantities of green leaf are puddled into the soil is in contradiction to the view that decaying organic matter produces a soil condition injurious to paddy. However, it cannot be denied that a condition of paddy similar to that described as straighthead is by no means scarce in India.

In India a considerable proportion of the specimens showing this condition come from the districts of Raipur and Bilaspur in the Central Provinces. A small percentage of these specimens are parasitized by *Sclerotium Oryzæ* Catt. but in the remainder no causal organism has been found. In other cases, from the Punjab, Burma and Assam, paddy showing these symptoms has been found infected with a fungal parasite, probably a species of *Cephalosporium*. The part which this fungus may play in causing paddy disease is at present obscure but, allowing for a proportion of damage due to these parasites, there remains in specimens from the above areas and from Bihar and Orissa and Kashmir a considerable amount of disease for which at present a satisfactory explanation, on a parasitic basis, is lacking.

In Italy the disease known as " brusone " has been attributed to the attack of *Piricularia Oryzæ*. This fungus is occasionally the

cause of serious damage to paddy in certain areas in Madras, and is also known in Japan, and is doubtless responsible for a proportion of the damage known as "brusone." The symptoms of "brusone" are a reddening of the plant, feeble development of the fine root system and lack of grain, the last two characters agreeing with the chief symptoms of straighthead. Brizi in a series of water cultures showed that a diseased condition of paddy could be produced by want of aeration, the condition of the roots in the non-aerated cultures resembling that of the roots of plants suffering from "brusone." Further experiments showed that the addition of an alga to non-aerated water cultures, in which the liquid contained a little CO_2 in solution, enabled the plants to produce a healthy growth. Brizi concluded that the algal film present on the surface of paddy fields must consume much of the CO_2 given off by the roots and largely increase the quantity of dissolved oxygen in the water. He states that "brusone" is generally worse in compact impermeable soils and especially in the presence of excess of organic manures which in their putrefaction lead to intense reduction.

The important fact which emerges from these experiments by Brizi is that a diseased condition of paddy has been shown to be dependent upon a deficiency in the supply of oxygen to the roots. This however can scarcely be accepted as an explanation of "brusone", as not all impermeable soils produce this condition and the disease is also known to occur on percolating soils. More extensive knowledge of the biochemical processes involved in the activity of the micro-organisms of soils is required before we can postulate any general cause for this group of diseases.

IMPRESSIONS OF THE INTERNATIONAL POTATO CONFERENCE, LONDON, NOVEMBER 1921.

BY

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THE First International Conference dealing with the potato, its culture, breeding, commerce and diseases was held in London on November 16, 17 and 18, 1921. This conference owed its being to the Royal Horticultural Society, acting in conjunction with the Ministry of Agriculture. The meetings proper of the conference were held in the lecture room of the Royal Horticultural Society's building in Vincent Square, that Mecca of British horticulturists. A full account of the conference will appear in the publications of the Society shortly, and it is understood that the papers read will also be printed in full. It is not the purpose of the writer to go into exhaustive detail regarding either papers or discussions, but merely to mention various points which struck him personally.

A limited number of galley proofs of papers were available at the beginning of each meeting. The readers of papers did their best to be brief, often omitting considerable passages (which were of course in type), but even with this abbreviation one felt that one would have liked more time for discussion. Such opportunities for the exchange of views between workers in different countries are so rare. One would have liked, too, some additional time for the informal exchange of views.

Experience of this and other conferences forces one to the conclusion that all papers should be circulated to members at least a

week before the meetings and that the whole time of meetings should be devoted to discussion led off by some chosen speakers.

In the discussions there revealed itself the old antagonism between the practical man and the scientist. This was good natured certainly, but unmistakable.

The farmer who grows potatoes for profit and the firms or individuals who produce new strains for commercial purposes are fairly well satisfied with themselves and not fully convinced of the necessity of more science. The attitude is perfectly just, since if the scientific man is not indispensable he is not wanted at all. In the combating of diseases the help of the scientist is, one thinks, always welcome, if he can give some real remedy or show that he is on the way to a remedy. In the realm of breeding, so far as the potato is concerned, the commercial grower has certainly done wonders, and the scientific student of the genetics of potatoes is only a little way on the road yet. In this matter as in others, and in all countries, it seems to the writer that the scientific man has to make known even yet what the method of science is in order that he may convince the public who pay him that with this method results are certain and that when the results are obtained progress even in the directions in which practical men have done most is bound to be both more rapid and more secure.

The help which the scientific man can give was well illustrated in the discussion on bud variation of potatoes. There has been considerable discussion of this point in gardening papers recently with a good deal of argument both for and against. This discussion was renewed at the meetings of the conference. By bud variation in the potato has been so far meant bud variation in tubers, *i.e.*, the production of aberrant tubers. Now there is no *à priori* reason why this should not occur but satisfactory.

There is no reason why the practical man should not use the scientific method. His results would be no less good and his explanations of them would be not only sounder but such as would lead himself and others further along the line of powers over nature.

Much of the interest of the meeting was centred on wart disease. This has not yet been found in India, and the statement of the

Indian delegation to this effect elicited the fact that wart disease is also unknown in France although it has been open to infection from potatoes imported from Britain and from the crops grown by the Germans during their occupation. No Italian delegate being present, it was impossible to learn directly whether Italy, the source of most of the Indian seed potatoes, was, like France, also free from wart. There is something here rather mysterious.

The discussion brought out clearly the fact that the causes of immunity to wart are not known. One pathologist put forward the theory that immunity might not be permanent and might break down. In this direction there is certainly room for much fundamental research. The potato blight due to *Phytophthora infestans* (which does not trouble the potato crop in the plains of India) was the subject of some discussion. The oospores of this fungus have now been found and they or the perennating mycelium or both may be responsible for the passing on of the disease from one season to another.

The experiments on the inheritance of wart disease described are too immature yet to permit of any definite opinion, but the extraordinary fact was put before the meeting that both immune and susceptible varieties produce a progeny in which some seedlings are susceptible and some immune.

Until a true breeding immune or susceptible race is discovered, therefore, it is impossible to analyse satisfactorily the genetic constitution of the commercial varieties, many if not most of them being of very mixed descent.

Of the other diseases dealt with, the obscure group including mosaic and leaf curl attracted a good deal of attention, the more because the well-known Dutch scientist, Dr. Quanjer, whose work on these diseases is well known, was there in person to deal with the subject. These diseases have not been noticed by workers in India as far as the writer is aware.

The Indian delegation put before the conference their difficulties regarding soil fungi and storage rots but there was very little discussion on these matters. It is worth noting that India was the only tropical country represented, and as the problems of potato growing

in the tropics are undoubtedly special there was not so much discussion on the tropical aspects of the various questions.

This is not to be taken as meaning that the Indian point of view did not receive attention. Throughout the conference the Indian delegation were heard with interest, and in the first meeting the writer was specially called on to explain the Indian situation.

The commercial uses of the potato were dealt within a comprehensive paper. Out of this paper and the discussion following it appeared that in Britain the production of potato farina has been a failure, while on the Continent, and particularly in Holland, it has been successful. Japanese competition, however, was now tending to interfere with the Dutch industry. One wishes that one could have heard someone who had actually been in the business.

The question of degeneration of varieties received considerable attention. The opinion was expressed by a representative of the breeding industry that it did not matter if a variety lasted only 20 years or so, as there would be many new varieties in the market by that time to take its place. Several scientists gave evidence that degeneration is a result of disease infection. The matter is another of the questions on which we cannot be said to have reached finality.

In conclusion, one may hope that this will not be the last of these conferences. The meeting of scientists and practical men of various countries is most valuable. The only thing necessary is that they should meet as much as possible during the time of the conference.

CONDITIONS INFLUENCING THE DISTRIBUTION OF GRAIN SMUT (*SPHACELOTHECA SORGHI*) OF JOWAR (*SORGHUM*) IN INDIA.*

BY

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THIS is the commonest smut of *jowar* in India, as in most countries where the crop is cultivated. It is also the most destructive disease in this country causing enormous losses, especially in Bombay, Madras, Central Provinces and Burma. It is, however, very scarce, at any rate not so abundant, in the Indo-Gangetic plains comprising the provinces of Sind, the Punjab, the United Provinces and Bihar, though it is met with in the submontane parts of the United Provinces and the Punjab. In a previous publication,[1] on the evidence obtained from the germination study of the spores of this fungus, it was suggested that *temperature* had an important bearing on the occurrence of the disease. The results of the potculture experiments carried out since then have given ample proofs of this fact and they have been confirmed by field trials. The account given below contains the details.

In order to follow these experiments a short account of the results of the previous work[2] will be necessary and therefore has been quoted.

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* Paper read at the Eighth Indian Science Congress, Calcutta, 1921.

[1] Kulkarni, G. S. Smuts of Jowar (*Sorghum*) in the Bombay Presidency. *Pusa Agri. Res. Inst. Bull.* 78, p. 13.

[2] *Ibid*, pp. 12 and 13.

"In the case of *grain smut* infection occurs with seed-borne spores. The germ-tube of the spore or of the sporidium comes in contact with the young cells of the seedling. Entry is effected by the hyphæ growing through the epidermal cells of the primary shoot below the soil level, and the susceptibility is limited to the period of about 2 to 6 days between the moment of germination and the emergence of the first green leaf from its colourless sheath. This period varies somewhat according to temperature."

"At low temperatures *jowar* will germinate very slowly. Its rate of germination increases as the temperature rises and is at its optimum at 36°C. to 40°C. Thus at 16°C. it takes from 4 to 6 days for the first leaf to appear. At 20° to 23°C. it requires 3 to 4 days, at 30°C. 2 to 3 days, and at 37°C. 1½ to 2 days. The spores of the grain-smut germinate quite easily at moderate temperatures. The optimum temperature is 20° to 23°C., below or above which the rate of germination falls. At 16°C. about 70 per cent. of the spores germinate, at 20° to 23°C. about 90 per cent., at 30°C. about 60 per cent. and at 37°C. only 1 to 2 per cent., while at 40°C. nil. If the temperature of germination be compared for the spores and the *jowar* seeds, it is found that infection is most likely to succeed at moderate temperatures, say, between 16°C. and 30°C., at which the spores germinate very freely, while the growth of the *jowar* seedling is retarded so that the susceptible stage is prolonged."

Usually *jowar* is sown in India in June-July, when the average temperature of the places where *jowar* is cultivated, *viz.*, in Bombay, Madras, Central Provinces and Burma, is between 21° and 30°C. This temperature being most favourable for the spores to germinate, *jowar* grows up rather slowly and consequently the susceptible stage is prolonged and infection is more certain. In the Indo-Gangetic plain, however, where the average temperature for these months is between 30° and 40°C., which is too high for the spores to germinate but more favourable for the rapid growth of *jowar* seedlings, the susceptible stage is passed over soon, and therefore infection is very little.

In order to test this assumption, pot experiments were done in the Mycological Laboratory of the Agricultural College, Poona. A small quantity of *jowar* seed was taken and was infected with the fresh spores of the grain smut.

Infection was done by sprinkling the spores on the grain. The seed was then sown into two pots. One pot was incubated at 40°C. for three days, and the other at 25°C. which was the room temperature of the laboratory. On the fourth day the pots were taken out and the seedlings were transplanted in big pots, and were kept under observation till the plants flowered. The results were as under :—

Serial No.	No. of plants in each pot	No. of smutted plants	Remarks
Pot No. 1 ..	20		
„ „ 2 ..	13	nil	At the time of germination incubated at 40°C. for three days, afterwards transplanted into four pots.
„ „ 3 ..	14		
„ „ 4 ..	22		
„ „ 1 ..	17	9	
„ „ 2 ..	12	6	At the time of germination incubated at the room temperature of the laboratory, *viz.*, 25°C., and then transplanted into four pots on the fourth day.
„ „ 3 ..	21	12	
„ „ 4 ..	14	8	

In the first series of pot experiments there was no smut attack, since no infection took place as the spores do not germinate at 40°C. temperature, while in the second series the attack was due to the free germination of spores at the low temperature of 25°C. It thus clearly shows that temperature is a limiting factor to the smut attack of *jowar* crop.

Field experiments.

These experiments were carried out at Pusa * in Bihar, and at the Government farms at Larkhana and Jacobabad in Sind, with the following results.

Place	Treatment of seed	Average temperature at the sowing time	Percentage of attack
	Experiments in 1918.		
Pusa plot	Seed was mixed with spores before sowing	27° to 32°C. from 26th to 30th June, 1918.	12
Larkhana plot	Do. ..	26° to 34°C. from 22nd to 26th July, 1918.	10
Poona College Farm plot (Control).	Do. ..	27°C. from 26th to 29th June, 1918.	32
	Experiments in 1920.		
Jacobabad plot	Seed was mixed with spores before sowing	36° to 40°C. from 11th to 14th July, 1920.	nil
Poona College Farm plot (Control)	Do. ..	25°C. from 19th to 21st June, 1920.	65

Smut appeared on the Pusa and Larkhana plots in 1918 owing to the exceptionally low temperatures that prevailed at sowing time. The degree of attack was, however, much less as compared with that of the control plot where it was 32 per cent. The results of 1920 at Jacobabad are, however, quite definite. Smut attack was nil owing to the high temperature at sowing time, while it was considerable in the control plot (65 per cent.)

These experiments, therefore, both in pot and field, go to show that *temperature* is the controlling factor in the distribution of the grain smut in India.

* Writer's thanks are due to Dr. Butler, Imperial Mycologist, Pusa, and to the Farm Superintendents of Larkhana and Jacobabad for having carried out the field experiments.

Selected Article

THE PROBLEM OF THE WITCHWEED.*

BY

H. H. W. PEARSON, Sc.D., F.L.S.

General.

THE witchweed (*Striga lutea*, Lour.), also known in various districts as the redweed, rooibloem, rooiboschje, mealie-gift, isona, molvane, etc., is a root parasite belonging to the family Scrophulariaceæ, which includes many other species living in the same manner. These are all flowering plants whose roots become intimately attached to those of other plants, from which they derive some or all of the food material which they require. The loss of material which is thus suffered by the plant attacked (the "host" plant) causes it permanent injury; its growth and development are impeded, and frequently it dies before reaching the seed-bearing stage.

These root parasites are very numerous and are found in all the habitable parts of the world. In a state of nature, growing upon wild plants native in the same locality, they are not as a rule productive of great harm. A condition of equilibrium, resulting from a long-continued struggle for existence between contending species, has been established. The host plants are able to hold their own against the parasite; on the other hand, the parasite, increasing perhaps at one period and waning at another, continues to exist and set seed. But when new land is cultivated these conditions of equilibrium are destroyed. If the crop grown on newly broken soil should be a suitable host, the parasite, once established on it, is likely to increase and multiply very much more rapidly than

* *Dept. Agri. Union of South Africa Bull.* 40.

ever before; and if the crop is cultivated over a wide area it may quickly spread over a whole country. Consequently it is not surprising that, with the rapid extension of agriculture during recent years, parasites of various kinds and root parasites in particular, formerly unknown, have many of them become of great economic importance. In South Africa there are perhaps 150 species of root parasites growing wild upon the native vegetation in various parts of the country. So far only one of them, the witchweed, has become well known as a parasite upon cultivated field crops. At least two others, however, occur occasionally, and there are others which may at any time force themselves upon the attention of the farmers of the country.

The witchweed is probably a true native of South Africa. It occurs quite commonly in uncultivated land as a parasite upon various native grasses in Zululand and Natal and, occasionally, in the Transvaal. It is, however, probable that originally it was confined to the south-eastern coast belt and has spread inland with the extension of maize cultivation. It occurs also abundantly in Tropical Africa, Egypt, Madagascar, Arabia, Ceylon, Bengal, Punjab, Sind, Deccan, Siam, Java, and China. Outside Africa it apparently does not inflict serious injury upon any field crop, though in India it is said to be of common occurrence in the rice-fields.

The root parasites may be divided into three classes, according to the extent of their parasitism and of the injury which they inflict upon their hosts. Very many of them—the least harmful—are green plants, with small but green leaves which take little more than water from their hosts; such, for example, is the common English wayside weed popularly known as the "eyebright." Others are at first subterranean, subsisting entirely at the expense of the host plant for a few weeks, months, or years; at length the stem appears above the ground, develops green leaves, produces flowers and seed, and then dies. To this class the witchweed belongs; for a period varying from six weeks to three months its sickly white stems are not seen above the ground; their growth is supported entirely by the host plant. It is during this first part of its life that the greatest harm is suffered by the maize. There is a third class whose members never

become green at all; these are fed entirely by the host plants, and they are therefore more injurious than either of the two preceding classes. An example of these is the broomrape (*Orobanche*), which within recent years has done great damage to hemp, tobacco, and other crops in the southern United States and elsewhere.

The witchweed is now very widely distributed throughout the maize-growing districts in South Africa. As a parasite on the maize it is reported to occur in the following localities :—

Natal.

Alexandra.
Alfred.
Bergville.
Camperdown.
Dundee.
Entonjaneni.
Eshowe.
Estcourt.
Helpmakaar.
Hlabisa.
Inanda.
Ipolela.
Ixopo.
Klip River.
Lions River.
Lower Tugela.
Lower Umzimkulu.
Mahlabatini.
Mtunzini.
Ndwandwe.
Newcastle.
New Hanover.
Nkandhla.
Paulpietersberg.
Richmond.
Umgeni.
Umlazi.
Umvoti.
Utrecht.
Vryheid.
Weenen.

Transvaal.

Aapies River.
Amsterdam.
Barberton.
Bethal.
Bronkhorstspruit.
Carolina.
Elands River.
Gatsrand.
Groot Marico.
Hex River.
Highveld (2).
Klein Spelonken.
Klip River (2).
Krugersdorp.
Lake Chrissie.
Mapoch.
Nylstroom.
Ohrigstad.
Olifants River.
Palala.
Piet Retief.
Potgieter.
Roodekoppen.
Saltpan.
Secocoeni.
Selons River.
Springbok Flats.
Steelpoort.
Steenkoolspruit.
Swartruggens.
Upper Schoonspruit.
Waterval.
White River.
Witwatersberg.
Witwatersrand.
Woodbush.

Orange Free State.

Kroonstad.
Ventersburg.
Vrede.

Cape Province.

Fort Beaufort.

In spite of this very wide distribution in South Africa there are still many maize-growing districts in which the witchweed is not

known to have appeared or occurs so sparingly that it attracts no attention. This is particularly the case on the high veld and in the Cape Province*. Among the natural checks to its spreading, differences of temperature and of soil are probably paramount. The critical temperatures for the germination of the seed are not at present determined; it is hoped that definite information regarding this question will be obtained shortly. The question of the effects of soil differences will be referred to later.

In addition to the maize, it also finds favourable host plants in the sugarcane and the kaffir corn. At Potchefstroom it grows on the fodder-grass *Paspalum dilatatum*, and in one single instance it was found to have established itself upon the monkey-nut. These host plants and the native grasses on which it occurs so abundantly in the wild and semi-wild states are, however, none of them so favourable for its growth as the maize. It will be noted that it shows a marked preference for members of the grass family, and that it has become established upon at least one fodder-grass (*Paspalum*) of recent introduction into South Africa. Therefore, quite independently of its effects upon the maize, this parasite is deserving of careful attention. Any new fodder-grass may furnish a host as favourable to the demands of the witchweed as the maize itself. The parasitism of the witchweed upon the maize has become very serious, because for at least thirty years no serious attempt has been made to deal with it, and it has been allowed to spread over the country almost unnoticed. If the matter had been taken in hand some years ago, the difficulty of dealing with it would have been very much less than it is now. If, therefore, it shows any sign of growing luxuriantly upon a new crop, energetic measures for effecting its eradication should be adopted without delay.

The general appearance of the witchweed will be familiar to most growers of maize. * * * *

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* * * During the first few weeks of its existence it does not come above ground at all. Its stems and

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* No information regarding the native territories is available.

minute leaves have no green colour ; they are living entirely at the expense of the maize plant, causing a very serious drain upon its resources. If the maize plant is infected in the seedling stage, this drain comes at a time when it is least able to meet it ; it is still a young plant needing all the food it can get for the purposes of its own growth. Therefore we have a combination of circumstances calculated to cause the maximum of harm to the maize, *viz.*, a hungry parasite relying entirely upon the host plant for its food ; a host plant hastening to establish itself, having no reserves from which to meet these demands, and therefore compelled to satisfy them at the expense of its own growth and development. Consequently by the time that the witchweed appears above the ground the damage is done.

Botanical investigation.

The way in which the witchweed attaches itself to the mealie root was described by Mr. Fuller.[1] A number of branches from the lower part of the plant spread out in the soil and produce bell-shaped out-growths (haustoria), which fit closely on the surface of the root. From the mouth of the " bell " there arise out-growths which pierce the tissues of the maize nearly to the centre of the root and absorb its juices. The detailed structure of the haustorium and of the connection which it establishes with the tissues of the mealie root have been studied by Miss Stephens.[2] These structures resemble in all essentials those of the haustoria of many other root parasites. It is, however, necessary to refer to them here in order to make it clear that when once the connection is established nothing can be done to save the plant that is attacked. The disturbance caused in the soil by the ordinary methods of cultivation undoubtedly gives momentary relief by breaking some of these connections, but when the underground top of a young witchweed plant is broken off, the lower part branches more profusely, and, in the end, the number of connections established may even be greater than it was

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[1] Fuller, C. *First Report of the Government Entomologist, Natal*, 1899-1900, pp. 20–22, Plate V.

[2] Stephens, E. L. *Annals of Botany*, XXVI, p. 1067.

before. It is hardly necessary to point out that the damage to the maize bears a rough proportion to the number of connections ; two equal holes in the bottom of a water-tank will empty it more rapidly than one.

Since, then, we can do little or nothing for the host plant when it is attacked, we must consider whether it is possible to prevent the attack. To this end it is necessary to investigate the whole life-history of the parasite, particularly that part of it which immediately precedes infection.

It was quite clear at the beginning of this investigation that the maize became infected through the seed of the witchweed, but it was not certain that this was the only method of infection. This doubt has now been settled. The witchweed plant dies when it has set its seed, or when the maize plant on which it is living dies. It is a true parasite and has not the power to become a saprophyte. Like the maize, therefore, it is an annual*, and at the end of the season leaves nothing except the seed with which to start the next year's crop. Whether it is an annual in the wild state is not known. If not, then it has become one in adapting itself to live as a semi-parasite upon an annual host. This simplifies the problem to some extent, for it enables us to concentrate our attention on the seed.

The first points then to be investigated are the distribution and germination of the witchweed seed and the conditions which control them. Some of the characters of the seed have already been mentioned. It is very small and light (Fig. 1) ; it is produced in enormous numbers. Its dark coloured coat is rough and sculptured (Fig. 1). Mixed with a dark soil, it is quite indistinguishable, except by the aid of the microscope. These facts give a clue to the means by which, within a comparatively few years, the witchweed has spread over so large an area. In the districts in which maize growing is practised on a large scale, the rains fall in the summer ; the winters are dry. Strong winds, driving great clouds of dust in front of them, occur during the winter. If the dust arises from

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* See postscript.

a field whose soil contains witchweed seed, it is quite impossible that it should not carry some of the seed with it, for the seed is smaller, and bulk for bulk lighter, than many of the mineral particles of the dust. A gentle rain washes the seed into the ground ; if the rain is so heavy as to cause a surface wash, seed will be carried off by the flowing water ; this is, no doubt, the

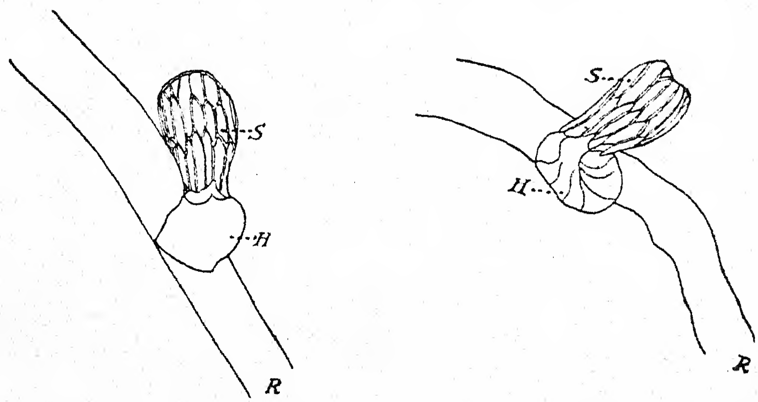

FIG. 1. FIG. 2.
R, Maize-root on which a witchweed seedling has established itself ; *S*, Seed-coat ; H, Primary haustorium.

explanation of the fact that the lower part of a field is frequently more thoroughly infected than parts which are at higher elevations. This is probably by far the most important method of seed distribution. If the maize seed were small and not easily separable from that of the witchweed, the question of distribution would be more complicated. A little seed is probably carried now and again with the maize from infected land, but this method of distribution can rarely be of great importance in comparison with that by the wind.

If, then, we can either prevent the witchweed from setting seed or destroy the seed before it germinates or kill the young witchweed seedling before it becomes attached to the maize root, the problem is solved. These alternatives may be considered separately.

The obvious method of preventing the seed being formed is to uproot the plant before it flowers. It is always possible to do

this by the ordinary methods of cultivation. It is only a question of labour supply and expense. This was pointed out by Mr. Fuller more than ten years ago[1]. It should certainly be adopted in all cases in which the infection is small. It has already been said that this treatment will not save that part of the crop which is attacked, but it will prevent the further infection of the land in following years. Where the crop is badly infected, it should be ploughed in before the witchweed flowers.

A few years ago it was attempted to obtain the same result by spraying[2] the witchweed plants with a solution of copper sulphate. These experiments were successful to a certain extent, but no development of this method is likely to be effective in dealing with the problem as a whole. If the maize plant is not well established, it will be injured as well as the witchweed. Although the aerial stems of the parasite may be destroyed, those which are still subterranean will hardly be affected, and in order to prevent the formation of seed the treatment must be repeated at intervals ; if the infection is abundant, the maize plant will be ruined as a crop before the witchweed comes above the ground. Therefore the risk to the maize plant and the expense of the treatment, if it is to be made really effective, are so great that it would probably be cheaper, and certainly better, to resort to the ordinary methods of cultivation.

Most of the root parasites of the same group as the witchweed are sun-loving plants.[3] There can be no doubt that the witchweed has the same character. Its production of flowers, and therefore of seed, would certainly be interfered with to a greater or less extent by the conditions of dense shade. Unfortunately the heavy infection of a maize crop brings in its train the reduction of shade, and therefore improves the conditions for free flowering and seeding. On the other hand, it is very probable that it is to some extent kept in check in the cane-fields of Natal by the dense growth of the sugarcane, which is sufficient to prevent direct sunlight from

[1] Fuller, C. *First Report of the Government Entomologist, Natal,* Pietermaritzburg, 1901.

[2] Watt, R. D. *Transvaal Agricultural Journal,* July 1909. Weir, C. W. *Agricultural Journal,* May 1911.

[3] Heinricher. *Die Aufzucht und Kultur der Parasitischen Samenpflanzen,* Jena, 1910.

reaching small weeds growing amongst it. At the same time there is every reason to believe that other and more important factors are concerned here, and it is likely that one of these is that the difference between the concentration of the cell sap of the sugar-cane and the witchweed is less than between the maize and the witchweed.[1]

The next point to be considered is the possibility of rendering the witchweed seed harmless after it has reached the soil. The small size, great numbers, and hard resistant coat of the seed make it difficult to kill. One condition which it cannot withstand is that of high temperature. In certain stages of its development it is not injured by being immersed in water at a temperature of 80°C. for fifteen seconds (Experiment 57). But it cannot resist temperatures considerably above that of boiling water. It has already been pointed out[2] that the burning of rubbish on the field after harvest will certainly kill the seed on the near surface of the soil. It will probably be only occasionally possible to put this into practice, but where it is possible it cannot fail to act beneficially on badly infected land by reducing the amount of living seed in the soil. It is further not improbable that there may be other methods, both more effective and more easily applied, of killing the seed in the soil. These are at present under investigation.

But even if the seed cannot be killed there are still other ways of rendering it harmless. One of these is to cease planting maize, for the present, on land known to be badly infected. Apart from the question of the conditions controlling the germination of the seed, which will be considered later, it is well known that up to the present the witchweed has not succeeded in establishing itself on a number of South African crops. In fact, as Mr. Fuller and others have urged before, "a rotation of crops is the correct treatment."[3] Long before the white occupation had extended to many areas on which maize is now grown, the Kaffirs were cultivating this crop year after

[1] MacDougall and Cannon. *The Conditions of Parasitism in Plants—Xenoparasitism* Washington, 1910.

[2] Pearson, H. H. W. *Agricultural Journal*, May 1912.

[3] Fuller, C. *L. c.*

year on the same ground until it became so thoroughly infected that its abandonment became necessary. A similar practice on a larger scale still prevails in very many districts. It is mainly to this fact that the present serious nature of the witchweed problem is due. For his own sake, as well as for that of his neighbours, a farmer who cannot command the means to cope successfully with a heavy crop of witchweed should use the badly infected parts of his farm for crops which are not attacked. Such crops are monkey-nuts, sweet potatoes, teff grass*, potatoes, velvet beans, kaffir corn†, lucerne, sunflowers, pumpkins, etc. The principle of the rotation of crops is now well established in intensive agriculture, and there is no need to discuss it here. It is only necessary to point out that it constitutes what will in nearly all cases be an easily applicable means of keeping the witchweed seed dormant, and therefore for the time being harmless.

There is still another possibility of putting the seed out of harm's way in certain cases, particularly in that of land recently infected. As a temporary measure it must be more or less effective; there is, however, no sufficient reason to hope that, in general, it can be of permanent benefit. The maize, as every one knows, is a shallow-rooting plant. If the land is ploughed as deeply as possible, the seed which lies near the surface will be buried so deeply that the maize will be well established before its roots penetrate far enough to be seriously infected. This in itself is an important gain, for early infection is much more harmful than that which occurs later. Also, when the witchweed seed germinates at some depth below the surface, particularly when germination does not occur until the maize is well grown, there is a considerable probability that the witchweed plant will not have time to reach the surface, and still more that it will not be able to flower and set seed. And further, it is probable that the conditions near the surface of the soil are more favourable for germination than those prevailing at a greater depth. If, then, the soil at the surface does not become reinfected by

* Reported to be immune.

† This plant is attacked, but usually the infection is so small that the witchweed is easily dealt with by cultivation.

wind-carried seed, deep ploughing should be beneficial until the land is deeply ploughed for the second time. The seeds of other root parasites whose life-histories have been investigated are known to remain alive for many years in the soil if no opportunity for germination presents[1] itself; there is a good deal of indirect evidence that the seeds of the witchweed possess the same property, and, *a priori*, it would be most surprising if they did not. It is therefore probable that at least some of the seeds buried by deep ploughing, if brought to the surface again within the following ten or fifteen years, will be still alive and able to infect a mealie crop as well as if they had never been buried. And in any case if, after ploughing, the surface becomes reinfected by wind-blown seed, we are no better off than before.

Germination of the seed.

We now come to the consideration of the germination of the witchweed seed and of the events which occur between the beginning of germination and the first infection of the maize-root. These must be carefully studied before we can make any reasonably promising attempt to prevent the infection.

Previous attempts to make the seeds germinate in cultivation had been unsuccessful[2]. The nature of Mr. Fuller's and other experiments is not described, but the fact that they were not successful made it probable that germination only occurs when the seed lies in the immediate vicinity of the root of a suitable host. While the seeds of many root parasites will germinate in the absence of a host[3], there are a few (*e.g.*, Tozzia) which behave differently. It is clearly of the greatest economic importance that there should be no doubt upon this point. If the seeds of the witchweed will germinate in clean soil in the absence of a host, the ordinary agricultural process of fallowing should suffice to free the land of witchweed. If, however, germination only occurs as the result of the action of a stimulus owing its origin to the presence of a suitable host, then the problem is greatly complicated.

[1] Heinricher. *L. c.* De la Germination des Graines des Plantes Parasites.
[2] Fuller, C. *L. c.*, p. 22.
[3] Heinricher. *L. c.*

During some months, therefore, various methods of germinating the seed away from a living host were tried ; all were unsuccessful. The seed was sown in water (drop-cultures), on damp moss, on porous pottery, on soil (including pure sand), and on gelatine. When no germination was obtained, it seemed possible that the addition of the expressed juice of the maize-root might give a different result. The experiments were therefore repeated, the maize juices being added to each of the substrata used before. Again no satisfactory result was obtained, the seeds sown on gelatine swelled and in a few the seed-coat cracked, but no root appeared. These methods were then abandoned, and for the time at least the conclusion was adopted that the seed only germinated in the presence of the host. This conclusion was considerably strengthened by the discovery that witchweed seeds of the same gathering as those used before germinated freely in the presence of a living maize-root. This is easily demonstrated in the following manner :—

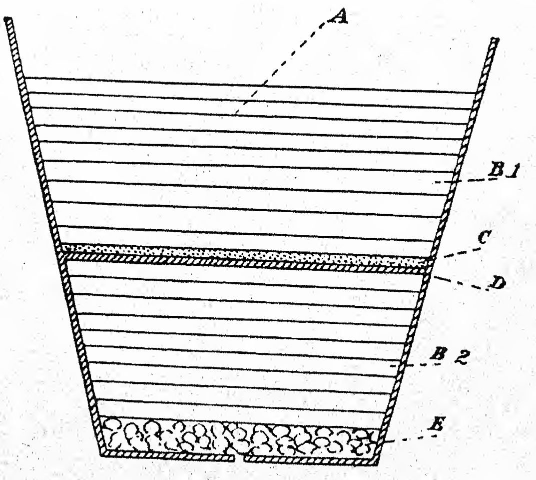

Fig. 3. Diagram of section through a flowerpot.
A, Maize seed ; B_1, B_2, Soil ; *C*, Mixture of sand and witchweed seed ; *D*, Layer of coarse muslin or silicate cotton ; *E*, Stones.

The culture, arranged as shown in Fig. 3, is kept sufficiently moist to ensure the germination of the maize and at a temperature ranging from about 15°C. at night to 25°–30° C. during the day. After 10–12 days, the pot is inverted and its contents are shaken out. On removing the muslin (D) and the soil B_2, which now lies

above it, the witchweed seed is exposed for examination. If the maize-root has grown into or through the layer C and other conditions have been favourable, young seedlings of the witchweed will be found.

The following conditions are necessary for germination :—

1. *Temperature.* Beyond the statement just made there is at present no precise information. The optimum temperature probably lies between 25°C. and 30°C.

2. *Soil.* That the nature of the soil is of great importance there can be no doubt. For example, on Springbok Flats contiguous areas of black turf and red loam soils bear very different crops of witchweed, though they must both contain abundant seed. Here we meet again with the old difficulty of the relative importance of the physical, chemical, and biological characters of the soil. The study of the agricultural soils in South Africa is not yet advanced beyond its initial stages, and the evidence required for a discussion of this difficult question is not available. The following analyses are, however, instructive :—

No. 1. *Comparative analyses*[1] *of three soils from Springbok Flats, viz.*—

A_1, A_2. "Black turf" (in which the witchweed germinates sparingly).

B. Reddish loam (in which the witchweed germinates profusely).

	A 1737 Per cent.	A_2 1738 Per cent.	B 1739 Per cent.
Stones	1·00	0·00	0·00
COMPOSITION OF AIR-DRY FINE EARTH—			
Moisture	5·96	9·11	9·45
Loss on ignition	6 01	7·17	7·37
Insoluble matter	70·89	63·02	62·49
Iron oxide and alumina	15·05	19·25	19·55
Lime	1·49	1·02	0·75
Magnesia	0·17	0·10	0·12
Potash	0·30	0·45	0·46
Phosphoric acid	0·07	0·07	0·08
	100·94	100·19	100·27
Nitrogen	0·126	0·133	0·137
Available potash	0·0083	0·0140	0·0120
Available phosphoric acid	0·0143	0·0059	0·0050

[1] *Report of the Department of Agriculture*, 31st May, 1910, to 31st December, 1911. *Appendix XIX* (*Report of Division of Chemistry*), p. 379.

For a second pair of analyses I am indebted to the courtesy of Mr. E. R. Sawer (formerly Director of the Cedara Experimental Farm) and of members of the scientific staff of the station.

Central Experiment Farm,
Cedara, Natal,
24th, February, 1912.

No. 2. *Reports on samples of soils taken by the Biologist from the farms Driefontein and Waterfall, near Cedara.*

I. Soil from upper portion of Driefontein farm, near Isaac Mkize's kraal; never known to have grown witchweed. Dark clayey loam, containing a fair amount of gravel of impure limonite.

II. Soil from lower portion of Waterfall farm, near the railway line, from ground known to be badly infected with witchweed. Dark red loam, with only a small proportion of sandy matter, but fairly porous owing to excessive amount of iron oxide present.

Results of analysis.

	I. Driefontein Per cent.	II. Waterfall Per cent.
Gravel	0·9	0·4
Reaction to litmus ..	Neutral	Neutral
Hygroscopic moisture ..	8·36	11·0
Loss on ignition	7·87	10·91
Total lime (CaO)	0·24	0·33
Total potash (K_2O) ..	0·09	0·12
Total phosphoric oxide (P_2O_5) ..	0·10	0·12
Chlorine	0·009	0·007
Nitrogen	0·18	0·18
Available potash	0·011	0·035
Available phosphoric oxide ..	0·002	0·002
Water capacity (capillary water)	41·9	42·0
	mm.	mm.
Capillarity—After 1 hour ..	79	92
" " 12 hours ..	231	277
" " 24 " ..	299	345
" " 120 " ..	513	548

Mr. Sawer further states with reference to these analyses: "The soil from the Waterfall farm, which is badly infected with witchweed, is, however, in every respect a better arable type than that from the Driefontein farm."

Many experiments to test the germination of witchweed seeds in the two types of soil from Springbok Flats ("black turf" and "reddish loam") have established the fact that the seeds germinate readily in the reddish loam and sparingly in the black turf. If this difference of behaviour is due to differences in chemical composition of the soil, we should expect them to be well marked. If the samples A_1 and A_2 represent approximately the range of variation in the composition of the "black turf," there is no such marked difference between this and the reddish loam. It is true that the latter is relatively poor in lime, but only to the extent of 0·27–0·74 per cent. But at Koedoespoort a soil, not very different from the Springbok Flats reddish loam, produces an abundant crop of witchweed even after a generous dressing with lime.

In the partial analyses of the two Cedara soils there is likewise disclosed no chemical difference which is at all likely to account for the absence of witchweed from No. 1 and its abundance in No. 2. On the other hand, nothing is known in this case as to the germination of the seed in these two soils, and the difference may be due to other causes—such as, for example, some peculiarity in the situation of Driefontein which has so far protected it from becoming infected. It is therefore impossible to draw any conclusions as to the relations between the composition of these soils and the germination of witchweed seed. From the Springbok Flats results, however, we may probably conclude that the more ready germination of the seed in one soil than in another is not due, at least in the main, to differences of chemical composition.

It is much more probable that differences in physical constitution rank high among the determining factors. The soils from the Springbok Flats, called respectively "black turf" (A_1, A_2) and reddish loam (B), are physically very dissimilar. The former is of clayey consistency, adhesive when wet, hard when dry, and comparatively retentive of water. The red loam, on the other hand, is loose and porous, sandy when dry, and quickly "dried out." There is reason to believe that the germination of the witchweed seed is greatly favoured by the physical conditions characteristic of the latter.

3. *Water.* Laboratory cultures have shown very clearly that the amount of water in the soil has a considerable influence upon the germination of the witchweed seed. Even in the reddish loam described above, germination may be entirely prevented by over-watering. So long as there is sufficient water to keep the

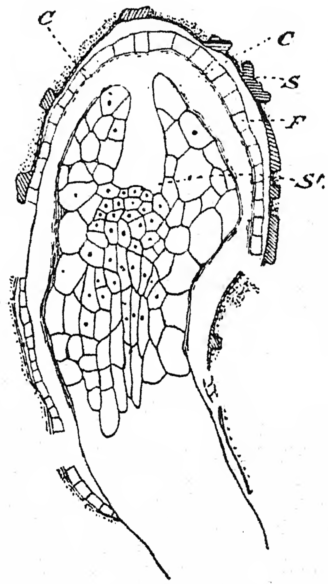

FIG. 4. A section through a germinating seed of the same age as those shown in Figs. 1 and 2. *S*, Seed-coat; *F*, Remains of food-reserve of seed; *St*, Young stem; *C*, Cotyledons of the embryo witch-weed plant.

maize plant alive, the drier the soil, the more profuse is the germination of the parasite. This result affords an explanation of certain facts well known to farmers. For example, in many districts it has been observed that the witchweed is much more abundant in dry than in wet seasons. Many farmers have found that a generous application of kraal manure tends to reduce the infection—an effect no doubt partly, but probably not entirely, due to the increased power of retaining water which is thus conferred upon the soil.

4. *Maturity of the seed.* Fresh seed (*i.e.* seed taken direct from the seed vessel just as it becomes ripe) will not usually

germinate even under the most favourable circumstances. In other words, the seed is not ripe when it falls to the ground. The ripening process is completed while it lies on or in the ground during the winter. Witchweed seeds collected near Pretoria and on the Springbok Flats in March 1911 were used in germination experiments in the winter of 1911, but without success. A quantity of this seed mixed with sand was buried 3-4 inches below the soil at Koedoespoort, near Pretoria, on 11th July. It remained there until the last week in October, when it was dug up and sent to Capetown, where it arrived on 30th October. On the same day a sample of this seed was placed in the manner described, below soil in which four maize seeds were sown. On 12th December one of the four maize plants was taken up, and three witchweed seedlings were found attached to its roots. On 28th December a second maize

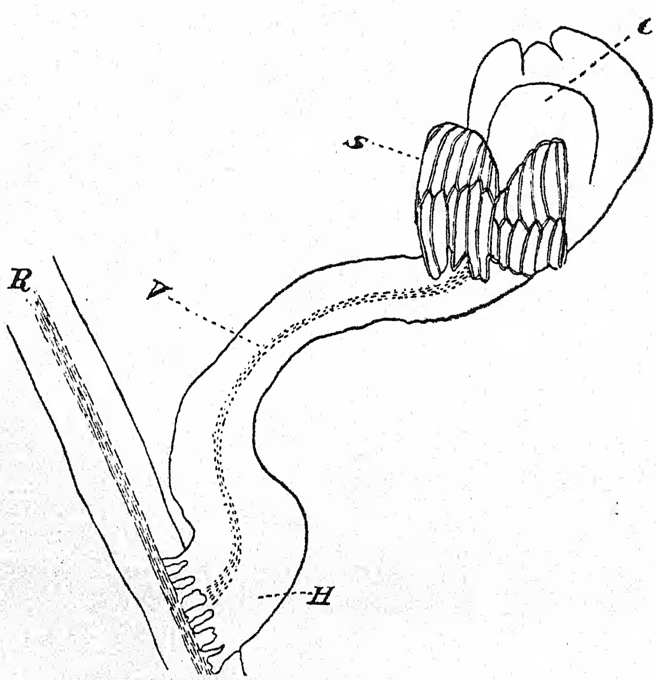

FIG. 5. An older seedling of the witchweed. In this case the root grew or some distance before coming into contact with the maize-root. *C*, Cotyledons of the embryo witchweed plant; *R*, Maize-root, on which a witchweed seedling has established itself; *S*, Seed-coat (The primary haustorium, *H*, seen in optical section); *V*, Vascular strand.

plant was found to be infected in more than thirty places. The third plant died and the fourth was broken during a storm. Clearly, then, a three months' exposure to the ordinary climatic conditions prevailing in winter and spring at Koedoespoort has produced such results that seed which was immature before the exposure has become mature. This behaviour agrees with that shown by other root parasites of this class.[1]

At the same time a very small proportion of a given sample of seeds will frequently germinate within a month or two of gathering if the other conditions are suitable. For example, a bundle of fruiting plants of witchweed were received in Capetown on 14th March, 1912, from Mr. Scott, of Fort Yolland (Zululand). The seeds were separated, mixed with sand, and exposed in a greenhouse six weeks later they were used in the following experiment :—

EXPERIMENT 79.

1912, 25th April.—Culture started as described on p. 174.
1912, 6th May.—Numerous germinations found.

The seed of the witchweed has another character in common with that of other root parasites—a peculiarity which has the effect of adapting it in a remarkable manner to the conditions under which it lives, but which has not been satisfactorily explained. Even after a winter's exposure to climatic influences all the seed in a given sample will not germinate even under the most favourable conditions. The proportion that will germinate is considerably below 50 per cent. The larger part appears to be still immature and will probably not be in a condition to germinate until the following or later years. Owing therefore to this progressive maturation of the seed, soil once infected is infected for a period of years. As to the length of this period there is no precise information for the witchweed. There is, however, some evidence to show that it is at least as long as twelve years. In other root-parasites the period seems to vary considerably. For example, in Tozzia and in Euphrasia the seed is stated to remain alive in the soil for many years [2]; seeds of

[1] Heinricher. *L. c.*
[2] Heinricher. *L. c.*

Bartsia, collected in 1895, were sown in February 1906, and germinated in 1907 [1]; seeds of the broomrape, *Orobanche ramosa*, planted in soil in 1889, produced seedlings each year until 1903[2] — some of the seed must, therefore, have remained alive in the soil for

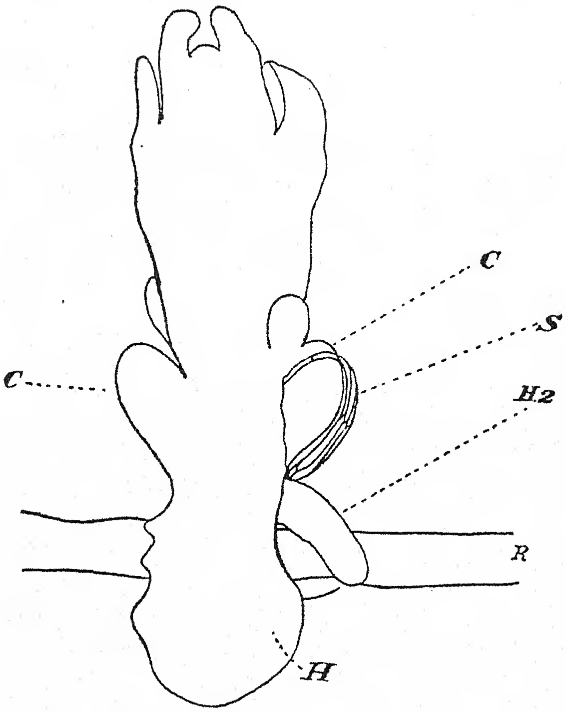

FIG. 6. An older seedling. *C*, Cotyledons of the embryo witchweed plant; *H*, Primary haustorium; H_2, A branch which will give rise to a second haustorium; *R*, Maize-root, on which a witchweed seedling has established itself; *S*, Seed-coat.

fourteen years; seeds of another broomrape, *Orobanche crenata*, on the other hand, lost their power of germinating after lying in the soil for eight years[3]. Although the length of the period during which the witchweed seed will remain alive in the soil is not yet determined, there can be no doubt that it more or less closely

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[1] Heinricher. *L. c.*

[2] Garman, H. The Broomrapes. *Kentucky Agri. Exp. St. Bull.* 105, 1903.

[3] Passerini. *Atti. R. Accad. Econ. Agri. Geogr. Firenze.*, [5], VII (1910), pp. 1–7.

resembles Tozzia, Euphrasia, Bartsia and Orobanche in the progressive maturation of the seed—a fact which greatly increases the

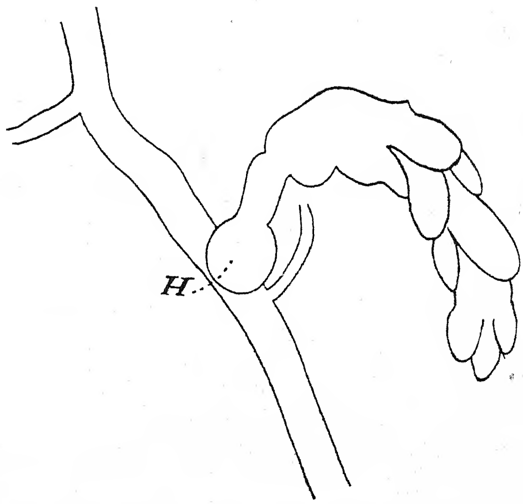

FIG. 7. An older seedling. *H*, Primary haustorium.

difficulty of eradicating it and emphasizes the necessity for using every possible means to prevent the shedding of the seed.

We now come to the details of germination. The narrow end of the seed (the micropyle) marks the position at which the root of the young witchweed seedling will emerge. The first obvious sign of the beginning of germination is a slight swelling at this point. This is followed by a cracking of the seed-coat, which exposes the white tip of the young root. The behaviour of this young root upon its emergence from the seed-coat is determined by the position in which the seed lies when it germinates. It has already been said that the presence of the maize-root is a controlling factor. Most of the seeds which germinate in a given culture will be those which lie in contact with the maize-root or so near to it that they are touched by the root-hairs. Actual contact with either the body of the root or with its root-hairs is, however, not always necessary. Occasionally a seed lying well beyond the range of the longest root-hairs will produce a seedling. In one case (Experiment 81) a few germinating seeds were as much as 3 cm. and several others 2 cm. from the nearest maize-root.

This last result occasioned some doubt as to whether the conclusion previously arrived at (p. 174) that the witchweed seed will only germinate in the presence of a host-root was correct. In order to test this the following experiments were carried out :—

EXPERIMENTS 112, 113, 114, 115.

13th May, 1912. These four cultures were arranged in the manner already described, but no maize seed was planted in either 112, 114, or 115. A maize seed was planted in the usual way in 113. The results were as follows :—

1912, 3rd June.—Culture 112.—Six witchweed seeds germinated.
1912, 3rd June.—Culture 113.—Maize germination failed. No witchweed seeds germinated.
1912, 3rd June.—Culture 114.—No germination. Soil, etc., replaced and re-examined on 19th June, when still no seeds had germinated.
1912, 3rd June.—Culture 115.—No germination.

As the supply of mature seed was small after June 1912, and was mostly required for other purposes, the results of Experiment 112 have not yet been adequately tested. The conditions were repeated in Experiments 138 and 139, but no germinations were obtained in the absence of a host plant. The details of 139 may be given here :—

1912, 3rd June.—Culture started as described on p. 174, without a maize seed.
1912, 4th July.—No witchweed seeds had germinated. Now added maize seed in usual way.
1912, 23rd July.—Maize plant strong. No germination of witchweed seed. Removed maize plant and planted fresh maize seed.
1912, 12th August.—A few young witchweed seedlings; many seeds swollen or slightly cracked at micropyle.
1912, 26th August.—Numerous witchweed seedlings.

While the peculiar result of experiment 112 is not yet explained, there is no doubt that germination of the witchweed in the absence of a suitable host-root, if it ever occurs under natural conditions, is rare.

The root of the young seedling, on emerging from the seed-coat, grows directly towards the nearest maize-root, even if it has to turn upwards in order to do so (Experiment 80). The directive influence exercised by the maize-root upon the first root of

the seedling is therefore sufficient to overcome the natural tendency of roots to grow downwards. If the seed lies in contact with the host-root, or very near to it, the root-tip of the parasite immediately forms a bell-shaped swelling (Figs. 1 and 2), which applies itself closely to the surface of the maize-root and gives rise to the first haustorium.* It is to be noted that the swelling begins to form before the tip comes into contact with the main root of the maize, though it may be that contact with the root-hairs supplies the necessary stimulus; also that the swelling in its first stages produces root-hairs.

If, on the other hand, the seed lies at some distance from the host-root, the first root of the seedling becomes much elongated† (Fig. 3) and only forms the haustorium when the contact is established. It is probable that a seed germinating at a considerable distance (say 1-2 cm.) from the nearest host-root never succeeds in forming this haustorium, and therefore does not cause infection. In these cases the elongating root usually assumes a more or less spiral form, as if it lacked a directive influence, such as the maize-root clearly exercises upon seedlings germinating in its immediate vicinity. The food required for the growth which occurs before infection is completed is supplied by the endosperm of the seed, which is gradually absorbed by the cotyledons, and probably also by the upper part of the hypocotyl (Fig. 4).

When the bell-shaped haustorium once becomes applied to the surface of the maize-root, one or more outgrowths quickly arise from the applied surface (Fig. 5 and Stephens *l. c.*, Fig. 6) and penetrate the tissues of the host. The maize plant is now infected, and the only practicable method of killing the witchweed is to kill the maize-root on which it has established itself.

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* This is not a suitable place for the discussion of questions of formal morphology. It may, however, be pointed out here that many authorities (*e.g.*, Goebel, Heinricher, etc.) regard haustoria of this character as organs *sui generis*; others (*e.g.*, W. A. Cannon) consider them to be modified roots. In Striga, as in Krameria (*cf.* Cannon, W A. Root-habits and Parasitism of *Krameria canescens*, Gray, 1910), the first haustorium of the seedling is a structure produced from certain tissues of the root-apex. While this does not prove conclusively that the haustorium is a modified root, it is nevertheless favourable to that view.

† The elongated region is no doubt a hypocotyl.

Soon after the stages now described, the terminal bud of the stem (Fig. 4) is set free from the cracked seed-coat (Figs. 5, 6), which usually adheres for some time to one of the cotyledons or to the lower part of the stem. The young stem now takes an upward direction (Fig. 6) and grows towards the surface. The rate of this growth varies within wide limits, and is no doubt determined by nutritive conditions, the precise nature of which is obscure. Probably the seedling stem grows very slowly, taking some weeks to reach the surface, when it is deriving its food supply from a very young maize plant; when, on the other hand, the maize plant is already well grown before the infection is established, there is reason to believe that the witchweed seedling grows much more rapidly.

In the following instance the maize plant was almost certainly infected very early in its history; it grew very slowly and in seven months attained a height of only 6 inches above the ground.

Experiment 46c.

1911, 24th December.—One Hickory King seed planted in pot of naturally infected soil from Koedoespoort, Pretoria.

1912, 24th February.—First witchweed plant appeared above ground.

1912, 27th February.—Second witchweed plant appeared above ground.

1912, 29th February.—Third and fourth witchweed plants appeared above ground.

1912, 5th March.—Fifth witchweed plant appeared above ground.

1912, 6th March.—Sixth witchweed plant appeared above ground.

1912, 8th March.—Seventh witchweed plant appeared above ground.

1912, 15th March.—Eighth witchweed plant appeared above ground.

Culture maintained until 19th June, but no other witchweed plants appeared.

We have, of course, no information as to the dates at which the eight witchweed seeds began to germinate, but from the knowledge furnished by other cultures it is probable that some of them produced seedlings within a week of the germination of the maize. This would give a period of about seven weeks for the subterranean growth of the witchweed. Incidentally it may be noted that this culture shows that a single maize plant may support as many as eight witchweeds and yet remain alive for seven months.

The primary root of the seedling produces a single haustorium. This does not long suffice for the rapidly increasing needs of the

growing stem. New roots arise from the lower part of the stem (Figs. 6, 8), and from these are produced in due course both lateral

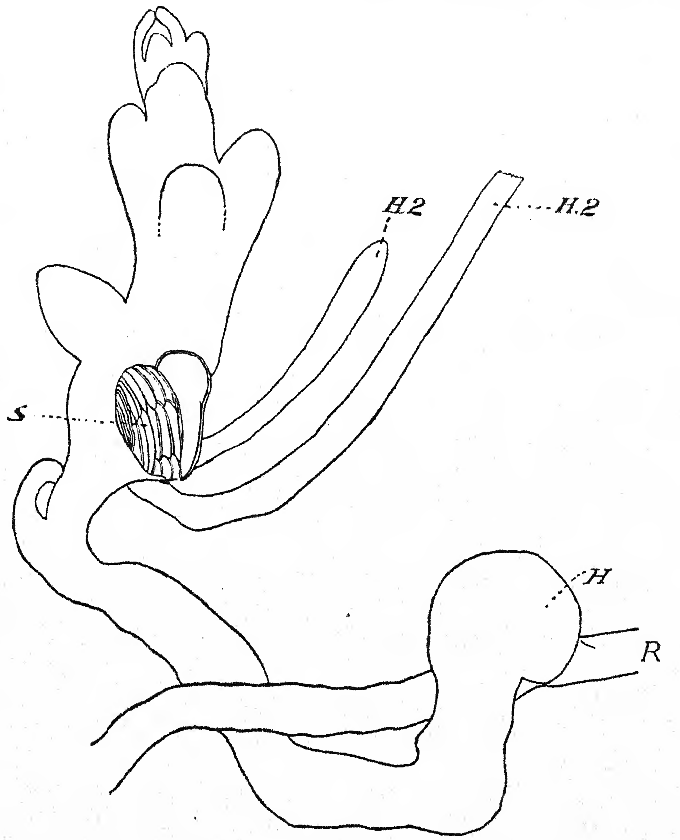

FIG. 8. An older seedling. *H*, Primary haustorium ; H_2, A branch which will give rise to a second haustorium ; *S*, Seed-coat.

and terminal haustoria,[1] resembling the first one in structure and in function. In this way a single witchweed plant can infect many maize-roots, which need not even belong to the same plant. With this insight into the manner in which the witchweed obtains its food supplies, it is easily realized that a crop of the magnitude of that described above has caused a very severe drain upon the neighbouring maize plants in the course of its growth upwards from the infected roots to the surface of the soil.

The information gained in this study of the germination of the seed has disclosed what may be described as the weak point in the

[1] Stephens. *L. c.*

life-history of the witchweed, *viz.*, the period during which the young seedling is making its way to the host. This period is short, perhaps never exceeding a few days. Any remedial measures that may be effective must be so used as to be available during this period. If infection is to be prevented altogether, these measures must be available throughout the whole period of growth of the maize-roots and at all points which they reach. In most cases this will be impossible for various reasons, some of which will be discussed later. The best that can be hoped for in a soil containing a great quantity of witchweed seed is to keep the maize free from infection during the first month or six weeks of its growth. Later infections do not, as a rule, ruin the crop, and the witchweed plants resulting from them are more easily dealt with by mechanical methods.

The destruction of the witchweed seedling.

The problem, then, is to kill the witchweed seedling before it has found and attached itself to the host. The means adopted must be such as will not also kill the maize. This excludes a number of well-known poisonous substances (*e.g.*, arsenic) which would undoubtedly be effective for the witchweed alone. Other poisons (*e.g.*, carbon bisulphide) which are frequently used on a small scale for similar purposes are useless here on account of the expense. But there are other substances (*e.g.*, copper sulphate), of which quantities which would not be sufficient to injure the maize might nevertheless destroy these delicate witchweed seedlings. Experiments on these lines are now being conducted, and it is hoped that definite results will be obtained in time to be tested in the field during the coming season. At the same time it is obviously undesirable to resort to such a method until all others have failed.

A more economical method would be the use of substances which would, at the same time, assist the growth of the maize and retard or altogether prevent that of the witchweed seedling. The study of such a method has been the principal subject of investigation during the past year.

The growth of a root in the soil depends, amongst other things, upon its powers to absorb fluids from the soil, *i.e.*, soil-water. This

power in turn is determined by the nature and the concentration of the solutions contained within the cells of the root. If, instead of ordinary soil-water, the young roots meet a solution sufficiently concentrated, then the fluid passes out of the root instead of into it, and this means the cessation of the growth of the root, at least for a time. If this abnormal condition can be maintained long enough, the root will be killed. Now we have two roots to consider, *viz.*, the maize and the witchweed. It is possible that the cells of the witchweed root will withstand a higher degree of concentration of the soil-water than the cells of the maize.[1] But even if this is the case, if the concentration of the soil-water is sufficiently high, the extreme delicacy of the first root of the witchweed justifies the hope that it may be killed before it has had time to adapt itself to the new conditions. The more robust maize-root will in the end almost certainly possess a greater power of adapting itself to higher degrees of concentration[2]. Also, it is not improbable that the concentrated solution absorbed by the seed in its early stages of germination may kill the embryo before the root emerges from the seed-coat. And there is a further, if perhaps smaller, possibility that certain substances known to exert a favourable influence upon the growth of the maize, either generally or in particular soils, may prove to have a directly poisonous action upon the seedling of the parasite.

Among common substances which can be used to increase the concentration of the soil-water for the objects above described, the following are the most effective in the order named (those bracketed together being equivalent) :—

1. Potassium citrate.
2. { Magnesium chloride.
   Calcium chloride.
3. { Potassium acetate.
   Sodium chloride.
   Sodium nitrate.
   Potassium nitrate.

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[1] MacDougal, D. T., and Cannon, W. A. *L. c.*

[2] Hill, T. G. Observations on the Osmotic Properties of the Root-hars of certain Marsh Plants. *New Phytologist*, VII (1908).

Of these substances, three, *viz.*, sodium chloride, sodium nitrate, and potassium nitrate,[1] particularly the two last, are known to possess considerable manurial value for maize. But in the case of the nitrate some of its manurial value must be sacrificed if used for the purpose described, for the best effects upon the maize are obtained when it is applied at least a month after sowing [2]; if it is to interfere successfully with the germination of the witchweed a much earlier application is necessary.

Many laboratory trials of salt and nitrate have been made. The substance was mixed with the soil above the layer of witchweed seed (B_1 in diagram on p. 174), for if applied in the field after the sowing of the maize it will not be possible to place it far beneath the surface. But as long as it is not too far from the place which will afterwards be occupied by the maize-roots, it will sooner or later reach it by diffusion. The following are examples of the results obtained :—

Experiment 52 (control).

1912, 26th February.—Infected soil from Springbok Flats in large pot. Two maize seeds planted.

1912, 4th March.—Maize plants appeared.

1912, 19th March.—Both plants stunted ; leaves discoloured and drooping. Uprooted one plant and found it to be infected with witchweed in many places.

1912, 22nd April.—Two witchweed plants up.

1912, 29th April.—Six witchweed plants up.

1912, 19th June.—Maize plant 18 inches high ; leaves small, discoloured and drooping. Small tassel appearing.

As the necessary temperature could not be maintained longer, the experiment was discontinued.

Experiment 53.

1912, 26th February.—Soil of same sample as in Experiment 52. Two maize seeds planted. 4 grammes sodium chloride (common salt) stirred in among the surface soil.

1912, 4th March.—One maize plant up. (The second seed did not germinate.)

1912, 19th March.—Maize plant much larger and more robust than that of 52 on same date.

1912, 22nd March.—Two grammes potassium nitrate stirred among surface layer of soil.

1912, 22nd April.—One witchweed plant up.

1912, 19th June.—No more witchweed had appeared. Maize plant 3 feet high, robust, forming cob.

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[1] Duggar, J. F. *Southern Field Crops*, New York, 1911.

[2] Duggar. *L. c.* Ingle, H. A. *Manual of Agricultural Chemistry*, London, 1908.

Experiment 54.

1912, 26th February.—Soil of same sample as in 52. Two maize seeds planted.

1912, 4th March.—Both maize plants up. 4 grammes sodium chloride stirred in among surface soil.

1912, 19th March.—Maize plants small, but robust, and apparently healthy. One plant uprooted. Infected by one witchweed seedling only.

1912, 19th June.—No other witchweed plant appeared. Maize plant had not tasselled, but otherwise appeared to be vigorous.

Since the soil used in these three preliminary experiments was obtained from the same sample and was therefore presumably uniformly infected, the results obtained permitted the conclusion that sodium chloride and potassium nitrate are effective in reducing the infection. These results were tested more precisely by cultures arranged as described on p. 174.

Experiment 88.

1912, 3rd May.—One maize seed. 0·5 gramme sodium chloride mixed with the soil B_1 (see p. 174). Witchweed seed from same sample (59a) as that used in Experiments 89, 90, and 91.

1912, 15th May.—Many witchweed seeds entangled in root-hairs of maize. Only one seedling had effected an attachment. Many of these seeds were swollen at the apex. Lower block of soil (B_2) and the witchweed seed were replaced in pot; a new lot of soil (B_1) added above, and a fresh maize seed planted.

1912, 3rd June.—One witchweed seed had germinated. The exposed root of the seedling was brown and shrivelled. No infection.

Experiment 89.

1912, 3rd May.—Conditions as in 88, but only half the quantity of sodium chloride (0·25 gramme) used.

1912, 15th May.—Thirty-four witchweed seeds entangled in maize root-hairs. Two of these had germinated, but in both cases the seedling root was shrivelled and dead. Other seeds were cracked at micropyle. Another maize rootlet was in contact with over 100 witchweed seeds. Two had germinated. The cells of one were plasmolysed; the other was dead. No infection.

Experiment 90 (control).

1912, 3rd May.—Conditions as in 89, but no sodium chloride used.

1912, 15th May.—Very numerous germinations and infections.

Experiment 91 (control).

1912, 3rd May.—Conditions as in 90.

1912, 15th May.—Hundreds of witchweed seeds had germinated.

Similar results were obtained by using nitrate instead of sodium chloride (Experiment 109, etc.).

These experiments justify the conclusions that (1) the substances used to exercise a deterrent effect upon germination, and (2) this effect is produced in the manner suggested (see p. 188), *viz.*, by causing the cells of the young root of the seedling to part with their fluid contents, as a result of which they become "plasmolysed" and later shrivel up. These results are obtained by the use of quantities which do not seriously interfere with the growth of the maize-root. But they give no information as to the period during which the substance, applied under the conditions prevailing in the field, may be expected to be present in sufficient quantity to be effective.

Another possible method of preventing successful germination is based upon the fact that most plants show a preference either for an acid, alkaline, or neutral nutritive medium; and in many cases a plant which grows normally in acid soil is starved or even unable to exist in a soil which is neutral or alkaline. A series of experiments soon showed that an acid medium is favourable to the germination—and perhaps to the maturation also—of the witchweed seed. This fact is indicated in the following experiments, which were, however, arranged for a different purpose.

Experiment 240 (control).

1913, 30th April.—Culture arranged as on p. 174. Witchweed seed from sample 116.
1913, 19th May.—Two germinations only.

Experiment 239.

1913, 30th April.—Conditions as in 240, but 4 grammes of flowers of sulphur mixed with soil.
1913, 19th May.—Soil smelt strongly of sulphur dioxide and therefore was acid. Witchweed germinations more numerous than in any culture previously examined.

(Experiments 237 and 238, in which smaller quantities of sulphur were used, showed similar results.)

An acid medium therefore suits the witchweed, at least in its early stages, and neutral soil is also favourable, though less so than the acid. It was therefore possible that an alkaline medium

would prove unsuitable. A satisfactory test for this was difficult to arrange. The soil can be kept alkaline for any requisite period by watering with weak solutions of alkalies, but this involves the use of a quantity of water sufficient to prevent the witchweed germination. It was therefore necessary to use a substance which in the presence of a small quantity of water will continually produce an alkali. Such a substance is calcium cyanamide. This is a valuable "fertilizer," and is likely to produce a beneficial effect by forcing the growth of the maize.

Calcium cyanamide in presence of water evolves ammonia. It was found by daily testing with phenol-phthalein that 2 grammes of cyanamide mixed with the surface layers of silver sand in an ordinary flowerpot, 6 inches in diameter at the top (Experiment 47), kept the soil alkaline for sixteen days. In order to apply this test it was necessary to water sufficiently to cause a slight drainage. With less water and a more retentive soil the alkalinity would probably be maintained for a longer period than sixteen days. If, therefore, an alkaline medium proved to be harmful to the germinating seeds, a single application of a suitable quantity of cyanamide should enable the maize to pass the first three weeks of its growth without danger of infection. This view was supported by the results of the following experiment :—

Experiment 87.

1912, 3rd May.—One maize seed. 0·5 gramme calcium cyanamide mixed with the soil B_2 (p. 174). Witchweed seed from the same sample (59a) as that used in Experiments 88, 89, 90, 91.

1912, 15th May.—No germination. Soil and witchweed seed replaced and new maize seed planted.

1912, 3rd June.—No germination.

The controls for this experiment (Nos. 90, 91) have already been described (p. 190). Similar results were obtained in other experiments in which the same or smaller quantities of the same substance were used. These seemed to indicate that germination was prevented by the ammonia evolved by the cyanamide.

Owing to a somewhat short supply of mature seed and the limitations of time, it was not possible to investigate further the

two methods now described before the beginning of the 1912-13 maize season. However, the results obtained were sufficient to justify their application on a larger scale in the field. These field-tests will now be described.

Field experiments.

In attempting to apply the results obtained in the laboratory to experiments in the field, we are confronted with certain difficulties. In the laboratory the conditions of the experiment are known and are subject to quantitative control for as long a period as may be necessary. If we attempt to stop germination by adding certain substances to the soil, we can ensure that the substance remains in the soil by regulating the amount of water. This clearly cannot be done in the field, and consequently the amounts of any particular substance used in the laboratory give little indication as to the amounts which should be used in the field. There is also another outstanding difficulty encountered in certain seasons in the field which is easily overcome in the laboratory. It follows from what has been said above (p. 167) that, other things being equal, the young maize plant suffers more than an old plant. It is therefore clear that in any method which may be adopted to retard the germination of the witchweed seed, the growth of the young maize should be as rapid as possible. In the laboratory experiments conditions favouring the growth of the young maize can be maintained. This is not the case in the field. Suppose, for example, it is possible to prevent the germination of the witchweed for a period of thirty days. If the growth of the maize is rapid, it should at the end of that time be past the stage in which infection is followed by the most disastrous consequences. But if the sowing of the maize is followed immediately by a drought, it may grow so slowly that at the end of the month it is still liable to be ruined by a comparatively few infections. Other complications arise from the varying composition of the soil, for a method that is successful for one soil will not necessarily be equally good for soils of different composition. To put down field-experiments without a preceding investigation under

laboratory conditions is to draw a bow at a venture with comparatively little chance of success; on the other hand, the application of laboratory methods to field-experiments opens up many difficulties, which, in the main, are due to the fact that these methods must be applied to the soil of whose composition and behaviour in the varying conditions prevailing in the open field very little is known.

Under the circumstances described, the amounts of the substances used in the experiments referred to above do not give any definite information as to the quantities that should be used in the field. Since the substances employed (sodium chloride, nitrate, and calcium cyanamide) have been used in maize cultivation for manurial purposes only, it was decided, in the first instance, to apply quantities which experience has shown to be suitable for the requirements of the maize. These quantities will at least not be injurious to the maize, and they should be sufficient to give some indication of their effects upon the germination of the witchweed and of the necessity of employing perhaps larger quantities to secure a better result.

Another disturbing factor that has to be reckoned with is the unequal distribution in the soil of the seeds of the witchweed. Therefore there must be borne in mind the possibility that the absence of witchweed from a particular experimental plot may be due, not to treatment, but to the absence of the witchweed seed. Then, further, the substances used in the experiment are either soluble in water or give rise to soluble products. An exceptionally heavy rain falling after they have been added to the soil must have the effect of diminishing the quantity of these substances in the soil layers which contain the maize-roots. Such a rain is described in the letter from Mr. C. H. Mitchell, which is printed below. The results of the experiments are therefore liable to be disturbed by exceptional conditions of drought or of rain. The latter difficulty may, of course, be usually overcome by fresh applications, which, however, are only possible so long as their cost falls within the limits of the profit on a normal crop. For it must be remembered that so long as the witchweed exists in any quantity in South Africa, there can be no complete and lasting eradication in any one district. Infection by wind-blown seeds it is impossible to prevent so long as

Plan of field experiments.

Plot 1		Plot 2		Plot 3		Plot 4		Plot 5		Plot 6		Plot 7		Plot 8
75 lb. salt added when mealie is sown.	Control.	Same as Plot 1, but sodium nitrate added 14 days later than in Plot 1.	Control.	50 lb. sodium nitrate added when mealie is sown.	Control.	Same as Plot 3, but salt added 14 days later than in Plot 3.	Control.	$37\frac{1}{2}$ lb. salt added when mealie is sown.	Control.	$37\frac{1}{2}$ lb. sodium nitrate added when mealie is sown.	Control.	$37\frac{1}{2}$ lb. calcium cyanamide added when mealie is sown.	Control.	75 lb. salt added when mealie is sown
50 lb. sodium nitrate added when mealie appears above ground.				75 lb. salt added when mealie appears above ground.				$37\frac{1}{2}$ lb. salt added when mealie is sown.	Control.	$37\frac{1}{2}$ lb. sodium nitrate added when mealie is sown.	Control.	$37\frac{1}{2}$ lb. calcium cyanamide added when mealie is sown.	Control.	75 lb. salt added when mealie is sown.
								$37\frac{1}{2}$ lb. salt added when mealie appears above ground.		$37\frac{1}{2}$ lb. sodium nitrate added when mealie appears above ground.		$37\frac{1}{2}$ lb. calcium cyanamide added when mealie appears above ground.		$37\frac{1}{2}$ lb. calcium cyanamide added one month after planting.
	A		B		C		D		E		F		G	
C O N T R O L.														

Each plot = $\frac{1}{2}$ an acre.
Plots 5—8 are divided into two $\frac{1}{4}$ acre patches.
Each strip labelled "Control" (A—G) = $\frac{1}{4}$ acre; it receives no treatment, but mealies are sown on it.

there are seeds to be carried. Therefore the cost of any remedy of economic value must be well within the limits of the profit of a year's crop.

It was intended that these experiments should be laid down on five different farms, and in this connection I have great pleasure in expressing my indebtedness to the following gentlemen for their kind co-operation, *viz.*:—

Mr. C. H. Mitchell (Bushy Vales, Fascadale, Natal).
Mr. A. E. Tidboald (Knapbrooke, Springbok Flats).
Mr. Weir (Koedoespoort, near Pretoria).
Mr. White (Springbok Flats).
Mr. Williams (Springbok Flats).

Owing to the severity of the early drought prevailing on their farms, Mr. White and Mr. Williams decided to postpone the experiments to a more favourable season. Mr. Weir was unable to lay down plots so large as those originally planned. Mr. Mitchell and Mr. Tidboald carried out the experiments completely.

I visited Mr. Tidboald's plot on 15th and 16th April last and that of Mr. Weir on 18th April. In both cases a drought prevailed at the beginning of the season and sowing was late. At Knapbrooke the plots were situated on the reddish loam soil, an approximate analysis of which has been given on p. 175. The following is the record kept by Mr. Tidboald :—

1912, 27th to 30th December.—All plots planted except portions of Nos. 7 and 8, which, on account of the state of the weather on 30th December, were not finished until 3rd January.

Later applications of the substances used were made at the times indicated on the plan. The rainfall during December amounted to 4·24 inches, distributed over twelve days (the falls on 30th and 31st December, respectively, were 0·8 and 0·72 inches). In January the total fall was 3·07 inches, spread over eleven days. On 9th and 13th January, respectively, the measurements were 0·55 and 0·58 inches. These were the only two days on which the falls exceeded

0·5 inch. Amounts of less than 0·5 inch falling within twenty-four hours are negligible in the high temperatures prevailing on the Springbok Flats in January. Therefore the plots were subject to an almost unrelieved drought during January, and consequently the early growth of the maize was very slow—a fact which militated against the success of the experiments.

The results on these plots as seen on 15th and 16th April were as follows :—

PLOTS 1 AND 2—Infection severe, but probably rather less than in the Controls A and B.

PLOTS 3 AND 4—Infection severe; probably worse than in Plots 1 and 2.

PLOTS 5 AND 6—Infection less severe than in other plots and than in the Controls D, E, and F. The best results were obtained with double application of nitrate in the lower half of Plot 6.

PLOTS 7 AND 8—No clear difference between these and Controls F and G. All badly infected.

At Koedoespoort the crop was more backward than at Knapbrooke and the indications, therefore, less reliable. The results were, perhaps, further complicated by the fact that part of the area covered by the plots had been manured during the previous season. So far as they could be read on 18th April, the results were similar to those described for the Knapbrooke plots. All the controls showed witchweed abundantly and fairly uniformly. Plots 1–5 and 7 and 8 were in no marked respect better than the controls. Plot 6 was superior to the rest in the size and stamina of the maize and showed less witchweed. Both these results were more marked in that half of the plot which had received a double application of the nitrate.

I have been unable to visit the plots at Bushy Vales. Mr. Mitchell has been so good as to send me the following report on the results observed there :—

Fascadale P.O.,
Natal, 24th May, 1913.

Professor H. H. W. PEARSON, Capetown.

DEAR SIR,

I am writing this line to give you the result of experiments with witchweed. I am sorry they have not been more satisfactory.

In the first case it was a very dry season, so that it was quite late before I was able to get the plot ploughed and planted. Then when the crop was nicely up we had that record rain—over 13 inches in less than a week—and that badly damaged the crop with big washes through it. In addition to that, it was not easy to get a large piece of ground uniformly bad with the weed; as you well know, the weed shows generally in patches, and even badly infected lands are not uniformly bad. When, therefore, I came to take results of the experiments it was, under all the circumstances, no use picking the crop and judging by the weight of mealies from each, as some were far more damaged by the water washes than others. The best I could do was to go carefully over the plots and, allowing for all the various items, judge on the ground as to general results. The result was certainly that sodium nitrate was most successful. Control A was very marked as between Plots 1 and 2, and Plot 6 was ahead of anything near it; 3 also showed well. As to the other plots, when I had allowed for certain of the field being less infected than other parts of it and for the damage done by the floods, I could see but little result from either the salt or the calcium cyanamide, except that, I should say, the Plots 1 and 2 were better than 5, but I cannot say if that was the result of the salt plus the sodium nitrate, or if it was not a better part of the field.

I am afraid this will not help you in the work, as we should both have liked, but it is not easy testing for this weed in the same way as one can test the result of a fertilizer on a crop. You can generally get a fair sized piece of land of equal value so as to give a fair test for fertilizers, but the patchy nature of this weed is against regular tests and the weather last season was all against us.

Next year I propose to plough and plant this piece of land across the plots, giving it very careful attention, and I should be able to judge better perhaps the second season than the first as to the killing effect of the chemicals used. Certainly sodium nitrate seems worthy of further testing.

Yours faithfully,

C. H. MITCHELL.

The results of these three series of experiments agree fairly well and seem to justify the conclusions that (1) the effect of the nitrate was distinctly beneficial, (2) the mixture of salt and nitrate was less effective, (3) the application of the salt made little difference to the witchweed, and (4) there was no result at all with the cyanamide. The nitrate certainly should be further tested, and it may be that increased quantities both of nitrate and of salt will give proportionally better results.

These results further suggest certain conclusions as to the nature of the action of the nitrate. As was pointed out above, it was expected to act in two ways, *viz.*, to produce (1) a quickening of the early growth of the maize and a consequent shortening of the period during which it is liable to be most seriously injured by the parasite, and (2) retardation of the germination of the witchweed seed. It was expected that the effect of the sodium chloride, if any, would be much less with regard to No. 1, but would be approximately the same as the nitrate for No. 2. We are therefore probably justified in concluding that the slight beneficial effect of the nitrate was due at least mainly to the early stimulation of the maize plant, and that its effect in preventing the germination of the witchweed seed was small. And yet in suitable quantities both the nitrate and the salt do produce this effect. It is therefore probable that the quantities present in the soil were not large enough ; this may be due either to the application of too small quantities or to the leaching out of these substances from the soil before they were able to make their influence felt.

Sodium chloride was employed some years ago at Kentucky in an attempt to save crops of hemp and tobacco from a root parasite whose habits in many respects resemble those of the witchweed.[1] So far as is known, the use of salt was not in this case tried on a large scale. The preliminary trials, however, indicated that with a surface dressing of salt of the amount of two tons per acre none of the seeds of the parasite germinated successfully, but the germination of the hemp seeds was also prevented for a period of three and a half

[1] Fuller. *L. c.*

months, and at the end of that time the soil still contained too much salt to permit of the free growth of the hemp. With half this quantity of salt (about one ton per acre) the infection of the broomrape was very considerably reduced and the germination of the hemp was fairly successful. This tends to confirm the view suggested above that the quantities of salt and nitrate used in the witchweed experiments were not large enough. But in increasing them we incur a double risk, for we may easily use so much as to stop the germination and growth of the maize, and, further, the amount necessary to produce the desired effect on the witchweed may be greater than the profit on the crop can stand.

The nature and extent of the investigations having now been described, attention may be drawn to the general question of the cultivation of maize on witchweed-infected land. It is probable that the nitrate and the salt can be used in quantities sufficient to check the germination of the witchweed seed. These quantities must, however, be limited by economic considerations, and it is not probable that these or other similar substances can be made effective throughout the whole period of the life of the maize plant. If infection during the early stages of the maize can be prevented, the crop will be saved. There are still the witchweed plants arising from seeds germinating late in the season to be reckoned with. These injure the maize plant, but will not as a rule prevent it from setting seed. But if they themselves are allowed to set seed a yearly infection of the land takes place. Apart from this, the presence of the witchweed plant in many districts in a wild state and in native maize patches constitutes a lasting source of re-infection. Some have hoped that in the natural course of things the parasite would "wear itself out," and that the problem would be solved by natural agencies. There is nothing impossible in this view, but it expresses a degree of optimism which, in the circumstances, is altogether unwise and unjustifiable. There is not the smallest real reason to hope that the present generation will see a diminution of the pest except as a result of properly designed repressive measures. On the contrary, it is rather to be feared that unless such measures are successfully applied throughout the witchweed area, its ravages will

become greatly extended, and maize cultivation on certain widespread types of soil will become impossible. The problem is therefore one of extreme gravity.

It is therefore not sufficient to save the maize crop. It will, in addition, be necessary to adopt every possible means of preventing witchweed plants from setting seed. This points to the urgent necessity of a more general application of the methods of intensive agriculture to the cultivation of maize. In stating this conclusion it is realized that a large proportion of those who are engaged in the maize industry are confronted with difficulties arising from shortage of labour and other causes. It must nevertheless be urged that there appears to be no reason to hope that the maize districts will ever be free from this pest, unless it is found possible either to obtain labour enough to keep the land clean, *i.e.*, to prevent the witchweed from seedling or to give up the cultivation of the maize on soils which are peculiarly favourable to the witchweed.

A further measure which cannot fail to reduce the rate at which the witchweed is now spreading is the adoption of a system of rotation of crops, as was urged by Mr. Fuller.[1] The maize is the only South African crop over which this parasite has obtained a complete mastery. In fact, there is no other which has yet been seriously injured by it. The ordinary period of a rotation is certainly not long enough to free the land of living seeds, but even if no seeds died within the period, their opportunity of producing a fresh crop would occur once in a period of years instead of annually as at present.

Where land is badly infected, there is one method of eradication which is perfectly satisfactory in all respects, save those of money and time. This, the method of "trapping," has been previously described[2]. If the field is sown with maize and ploughed up a month later, all the witchweed which has germinated in the meantime is destroyed. If this process is repeated often enough the soil will be cleared of witchweed seed. Four or five such crops during two

[1] Fuller. *L. c.*
[2] Pearson. *L. c.*

successive years would probably reduce the seed, in even a very badly infected field, to such numbers that intensive cultivation in later years would reduce the loss to a minimum. Poor soils would be improved by so much green-manuring. But the cost in many cases at least will be prohibitive. In such cases the land should be used for some crop which does not furnish a favourable host for witchweed.

I am indebted to Mr. J. Burtt-Davy for supplying me with information regarding the distribution of the witchweed; to Mr. I. B. Pole Evans and to Mr. H. J. Vipond for the hospitality of their respective laboratories; and to Miss E. L. Stephens and Miss H. J. Davison, who have assisted me with the experimental work, the greater part of which has been carried out in the Botanical Laboratory of the South African College.

P. S. Since the above was sent to press a letter from Mr. C. H. Mitchell and a paper by Dr. Heinricher ("Einige Bemerkungen zur Rhinantheen Gattung Striga," *Ber. d. D. Ges.*, XXXI, H.5.) have been received. The following extracts from Mr. Mitchell's letter are published, since they bear directly upon the feasibility of using large quantities of salt (see p. 199) to check the growth of the witchweed:—

"Fascadale P. O.,

"Natal, 6th June, 1913.

"There are two points arising from your letter that I wish to refer to. The first is as to the use of salt in large quantities. When the experimental plots were well up I was planting a very late field of mealies, and the plots 1 and 2 (see p. 195) looked so well then that I thought I would like to see for myself what a good dressing of salt would do on a piece of the late field that I knew was bad with witchweed. I told my son therefore, who was in charge of the ploughing, to broadcast salt over the part I knew to be badly infected. This was done, but as it was only for a trial to please myself, the ground was not measured, neither was the salt exactly; on one piece the salt was put on very thickly. This crop is now up and drying off; it is a poor crop, as all our late crops are this year. But the important

point I wish to mention is this : my sons assure me that over the land where the salt was spread broadcast there has been no sign of the witchweed, though in the grass lands near it has shown very freely. I have not made a personal inspection of that land, yet am quite satisfied with the statements made by my sons, as they are very keen."

In the paper cited, Dr. Heinricher questions the accuracy of the statement previously made that the witchweed completes its life-history during a single year. This statement has not been made for witchweed in the wild state, with regard to which the facts are not yet known. For witchweed as a parasite on maize, however, it is undoubtedly true. Apart from the fact that the maize is itself an annual, we have the results of the following experiment (No. 12) which are conclusive :—

1911, August 1st.—Witchweed seeds received from Mr. Claude Fuller (collected by him in Natal in July 1911). Seed mixed with washed and sterilized silver-sand.
1911, „ 2nd.—A pot culture prepared as described above (p. 174) but without a maize seed. The soil used was brought from Koedoespoort, Pretoria, and was carefully sterilized before being used.
1911, November 9th.—One Hickory King seed planted.
1911, December 13th.—Maize plant very small.
1911, „ 16th.— „ „ showing leaf discolouration.
1911, „ 20th.— „ „ with only five leaves of which lowest two are withered. Culture examined. Many witchweed seedlings found. Maize plant removed. Soil replaced in pot and watered with Sach's Culture Solution : two maize seeds planted.
1912, February 10th.—One witchweed plant appeared above the soil.
1912, „ 13th.—A second witchweed plant appeared.
1912, „ 29th.—First witchweed plant in flower.
1912, March 4th.—Flowers withering. Second witchweed plant in flower.

For prudential reasons these plants were not given an opportunity of setting seed. Similar results have been obtained in other experiments, and they place beyond doubt the conclusion that, as a parasite on the maize, the witchweed plant flowers in the same season as that in which the seed producing it germinated.

National Botanic Gardens,
Kirstenbosch.

Notes

PUSA PEDIGREE SANIWAL DAIRY CATTLE: ANNUAL SALE.

At the conclusion of the Meeting of the Board of Agriculture held at Pusa an auction sale of pedigree dairy cows and young male stock was held on the 18th February, 1922. The sale was well attended and most of the stock offered found a ready sale. Rs. 365 for a 2-year old bull was the top price. The cattle were shown in excellent bloom. Mr. Milligan, Agricultural Adviser to the Government of India, in opening the sale pointed out that the Pusa herd had now reached a stage at which the surplus stock exposed for sale were of excellent quality.

When the final accounts have been settled, it is expected that 60 head will average Rs. 150. The stock went all over India, and the distribution of such pedigreed stock throughout the country will be of value in improving dairy herds in India.

Mr. Wynne Sayer acted as auctioneer and managed to dispose of all the animals in 2½ hours. [G. S. Henderson.]

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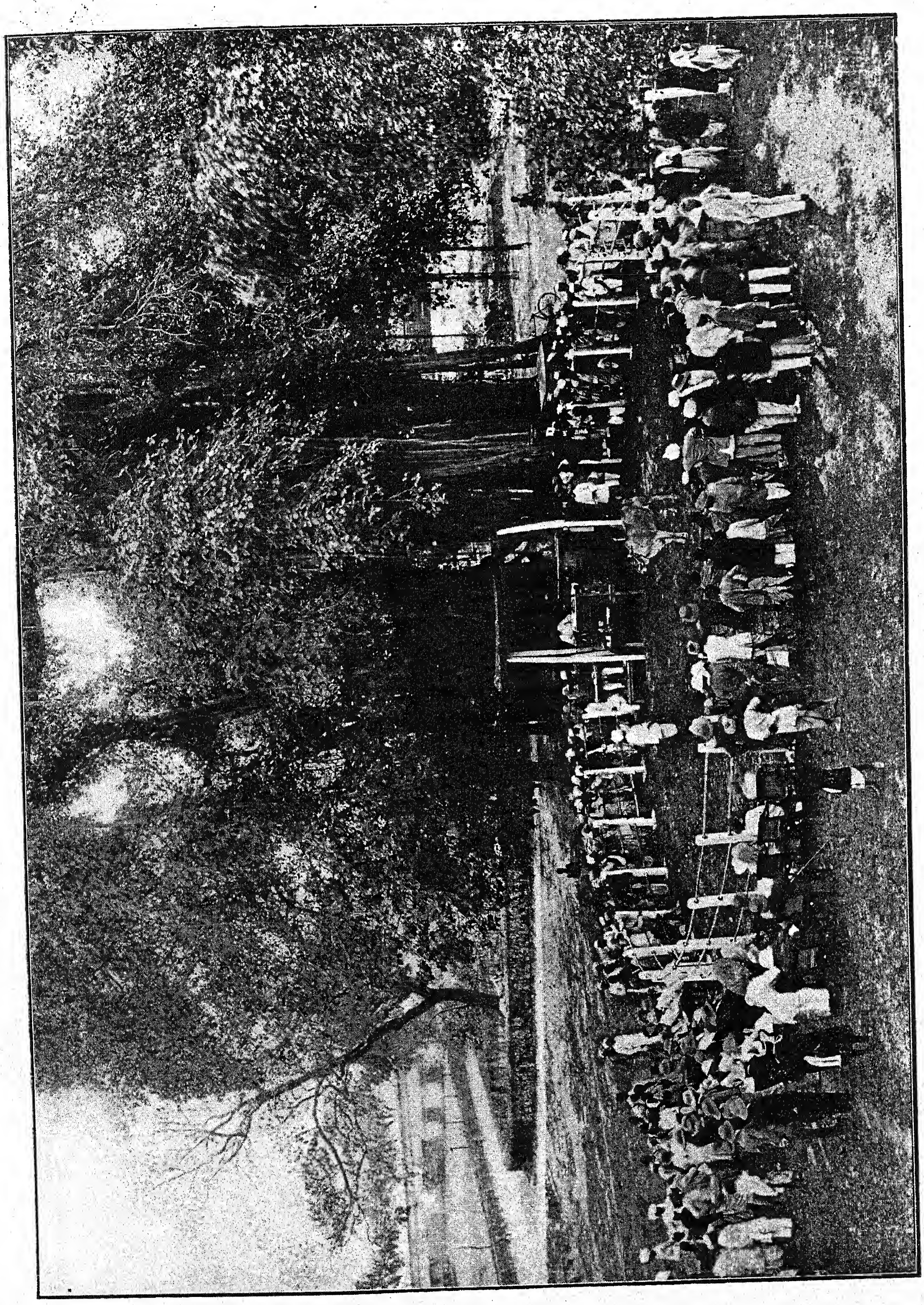
THE CONNECTION BETWEEN SEED-WEIGHT AND LINT-WEIGHT IN COTTON.

The question is often asked as to whether any attempt to increase the weight of lint on the seed of a cotton plant will mean also an increase in the weight of the seeds themselves, or whether it will be accompanied by a diminution of the seed-weight. In the case of Egyptian cotton the question has been answered by the work of Balls, in that of Sea Island cotton by the work of Harland, and in the case of Cambodia cotton by that of Hilson. All these investigators find that, for the cottons with which they have worked, an increase in the weight of lint *does* involve an increase in the weight

PLATE XI.



SALE OF PUSA PEDIGREE SANIWAL DAIRY CATTLE.

of seed, or, in other words, that there is a positive correlation between the two quantities, and they increase or decrease at the same time.

Does this correlation apply generally? We have had the opportunity of testing the point with three pure strains of the cottons of Gujarat, all belonging to the species *Gossypium herbaceum*. These were—

(1) *Goghari E*, a coarse, short staple type with a very high ginning percentage of 48 or over.

(2) *Surtee-Broach* 1 *A* (cylindrical boll type). This is a good quality Surat cotton with a ginning percentage of about 38.

(3) *Surtee-Broach* 1027 *A.L.F.* This represents the best class of Navasari cotton and hence the best staple cotton in Gujarat. Its ginning percentage is about 34.

On testing the question with about one hundred plants of each strain the conclusion of previous workers with other types of cotton was confirmed. In each case there was a positive correlation between weight of seed and weight of lint per seed, the actual figures in each case being as follows :—

	Co-efficient of correlation	Probable error
1. Goghari E	0·729	$\pm$ 0·03
2. Surtee-Broach 1 A	0·46	$\pm$ 0·05
3. Surtee-Broach 1027 A. L. F.	0·52	$\pm$ 0·049

Just as in other types of cotton, therefore, an increase in the weight of lint per seed involves usually an increase in the weight of the seed in the Gujarat *herbaceum* cottons. [M. L. PATEL.]

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SCIENTIFIC AND INDUSTRIAL RESEARCH.

THE Report of the Committee of the Privy Council for Scientific and Industrial Research, for the year 1920–21 (H.M.

Stationery Office, Price 1*s*.), like its predecessors, provides a most comprehensive and informative review of the entire field of activity of organized research. The textile industry as a whole figures largely in the report, as might be expected, and whilst a summary of the references to the activities in this important sphere may indicate the extent of the ground which is being covered, yet all who are interested in the vast movement of organized research should not fail to read the entire report if only for the purpose of securing comparative information as to activities in respect of the various industries affected, for it is to be remembered that industries are more or less interdependent. The report of the Committee of the Privy Council is a brief statement followed by the more exhaustive report of the Advisory Council.

The Committee points out that, in addition to the limitation of the estimates for the current financial year, they have caused to be prepared, in accordance with Government instructions, preliminary estimates for 1922-23 showing a saving of 20 per cent. of the estimates of the current year. The curtailment of resources, due to financial stringency, is causing both the Committee and the Advisory Council very great anxiety, and the limitation is certain to involve postponement of a certain amount of research work. For the year 1921-22, the estimates were reduced by 17 per cent.

The Committee specially mentions the important work undertaken during the year by the Fuel Research Board, a long series of experiments on the effect of steaming various coals in vertical gas retorts having been completed and a report issued. The expenditure on the Fuel Research Station during 1920-21 was nearly £50,000, whilst elsewhere than at the station the expenditure was £3,683, but over £3,000 was received by way of sale of by-products. The estimates for the coming year show an expenditure, after receipts, of about £55,000.

The number of industrial research associations now approved by the department is twenty-six, and during the year ending 31st March, 1921, grants to associations amounted to £74,557. The balance of the Million Fund then remaining unexpended was £903,205, and of this sum a large percentage has already been earmarked

for associations already formed. The total expenditure on special grants in aid of scientific investigations amounted to £20,912, and provision is made amounting to nearly £9,000 for their continuance during the current financial year. During the academic year 1920-21 one hundred and thirty-two allowances to students were made, seventy grants to research workers to undertake independent research, and forty-three grants to scientific workers to enable them to employ assistance or procure equipment.

The expenditure out of the vote of the department during 1920-21 was £462,650—made up of £373,821 from the Exchequer, £38,022 from interest of the Million Fund, and £58,806 from fees for tests, etc. The full total of expenditure of the department was £552,219.

The report of the Advisory Council covers from 1st August, 1920, to 31st July, 1921. Referring to the financial aspect of the work, it is stated that scientific research is the main, if not the only, source of fresh productivity in industry, and it is only by increased productivity that the world will find a way out of its present economic difficulties. Any reduction in the expenditure by Government on research which is considered by responsible men of science to be needed will react most rapidly, at the point where we are nationally weakest, on the number (not the quality) of competent investigators coming forward. The effect of even a temporary set-back will be long continued and may be lasting. It is certain, the report adds, that unless increased provision is made for the department in future years it will be impossible successfully to carry out the duties of co-ordination laid upon it by the Government in the interests of economy.

Referring to the British Cotton Industry Research Association, the Report says, the Association has begun investigations into the structure of cotton fibre; the effects of bacteria in causing deterioration of cotton and cotton goods; the constituents of raw cotton; and the moisture content and drying of cotton, defective sizing, the variation of tensile strength with twist, measurement of the regularity of yarn, strength of yarns, under a varying stress. Reports on these problems have not yet been issued for want

of adequate laboratory accommodation has considerably hampered the work. The Association, however, is looking forward to the time when its laboratories at the Shirley Institute, Didsbury, will be fully equipped. This Association has undertaken a survey of the literature relating to the cotton industry, and about 2,000 books and pamphlets have been catalogued. The Association has received considerable financial assistance from the trustees of the Cotton Trade War Memorial Fund on the recommendation of the Cotton Reconstruction Board. The Association has received the sum of £50,000, and it is understood that it will receive further contributions of £30,000 per annum for five years. This great accession to its funds, it is pointed out, will afford a good opportunity of demonstrating how organized research on a co-operative basis can be of benefit to all the branches of the industry. [*Journal of the Textile Institute*, November 1921.]

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QUEENSLAND COTTON GROWING : EXTENSION OF THE INDUSTRY.

The Australian Cotton Growing Association, Limited, has decided to begin operations in Queensland, where cotton has been grown for the past 50 years, having been first introduced at the time of the American Civil War. Cotton growing was then carried on profitably, but later it was abandoned owing to the lack of cheap labour such as was available in the United States.

This season about 900,000 lb. of cotton was produced in Queensland from 1,590 acres, and it is anticipated that a higher average will be attained later when the growers have acquired more experience. Judging by the applications received for seed for next season, it is estimated that 14,000 acres will be planted.

Discussing the prospects of the industry with a representative of "The Times" Sir James Hunter, Agent-General for Queensland, said that the increased cost of production in the United States and the higher prices obtained for cotton had made it possible to carry on the industry in Queensland with white labour. The land in that State cost only one-twentieth the price of cotton land in America.

Long staple cotton.

Mr. W. H. Johnson, F.L.S., has reported that the cotton growing area of the State extended for 1,300 miles along the coast and for 200 miles inland. Dealing with the northern belt, he said that the latitude, climate, and soil were similar to those of the American cotton belt, and being rather nearer the equator were less liable to damage from spring and autumn frosts.

Sir James Hunter added that the Queensland Government had intimated their willingness to make land available for the company. The Hon. Robert Vaughan was now on his way to Australia in connexion with the project. Mr. Armstrong, who had made repeated investigations into cotton growing in America and Egypt, would join Mr. Vaughan early next year. The company had placed an order for a saw gin which would be despatched and erected in time for the treatment of the coming season's crop. A smaller gin of the roller type to deal with the longer staple cotton which had been grown successfully in Queensland was also to be ordered. It was hoped that the longer staple variety would ultimately be the principal variety grown there. Samples of this long staple cotton had been tested by the Imperial Institute and by the Manchester Chamber of Commerce, and they were considered to be almost equal to Egyptian cotton.

Guarantee of 18*d.* per lb.

So far no cotton disease had appeared in Queensland, and every precaution was being taken to prevent the introduction of diseases by importations of infected seed.

"Last year," continued Sir James, "I arranged with the British Cotton Growing Association that it should guarantee 18*d.* per lb. for five years for long staple cotton of the quality that has been submitted to tests in this country, with a limit of £10,000 on the total loss to be borne by the Association. This was done to encourage cotton growing in Queensland, as it was found that farmers who had already engaged in other agricultural operations were disinclined to take up cotton growing without some such

guarantee. The first consignment of cotton under the guarantee scheme has just reached Manchester.

"It is possible that Italians or Maltese will be encouraged to take up cotton growing in the State. Settlers of the former nationality have already proved satisfactory in agricultural districts, being both industrious and well-behaved." [*The Times Trade Supplement*, 1st October, 1921.]

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COTTON RESEARCH.

THROUGH the courtesy of the British Cotton Industry Research Association, the Secretary of the Indian Central Cotton Committee has sent the following abstracts for publication :—

SHEDDING OF COTTON FLOWER BUD.

A general discussion of the causes of shedding in cotton in which attention is drawn to F. E. Lloyd's work and conclusions. In addition to the structural and environmental causes indicated by him, genetic factors are probably largely responsible for cotton shedding; for example, blasted buds are due to hereditary malformation of pedicels. [*Jour. Heredity*, 1921, **12**, 199–204. O. F. COOK.]

CONTROL OF BOLL WEEVIL.

The destructive power of the cotton boll weevil is increasing as the insect becomes acclimatized. The infestation is spreading rapidly throughout the American cotton-growing area. The Department of Agriculture states that the pest can be controlled by the application of calcium arsenate dust at the right season and in the right way. A proposal to prohibit the planting of cotton for one year has been made. Parasites which prey on the boll weevil are increasing in number and effectiveness. A method of fumigation of seed has been developed, as it is sometimes necessary to transport seed from an infested area. [*Text. Rec.*, 1921, **39**, 52-53. W. WHITTAM.]

Control of pink bollworm.

Fumigation tests have shown that infested seed can be satisfactorily disinfected by carbon bisulphide. Hydrogen cyanide, at atmospheric pressure, has not sufficient penetrating power to be effective to a greater depth than a few inches. The use of arsenical poisons in the field for the control of pink bollworm has yielded only negative results. The larvæ of the pink bollworm are very resistant to water, and have survived forty-eight hours immersion, and larvæ in dry bolls have survived a period of seven or eight days immersion. Careful study of malvaceous plants other than cotton have been made, to determine the possibility of their serving as hosts for the pink bollworm. In no case has the pink bollworm been found to infect any of these plants in Texas. [*Agric. News*, B. W. I, 1921, **20**, 90.]

Microtomy.

A rapid method for cutting microscope sections of cotton yarns and fabrics is described. Briefly it consists in mounting the specimen on a slide with cellulose acetate or nitrate solution applied in layers, stripping from the glass when dry, embedding in paraffin wax and cutting on a Jung microtome. Agar-agar has been found to be the best adhesive for mounting, and sections mounted in this medium will stand repeated applications of alkaline reagents without falling over. [*Jour. Text. Inst.*, 1921, **12**, 99-100. R. S. Willows and A. C. Alexander.]

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SUGGESTED PROGRAMME FOR FARMING IN SOUTH CAROLINA UNDER COTTON BOLL-WEEVIL CONDITIONS.

The Indian Trade Commissioner in London has kindly forwarded to the Indian Central Cotton Committee a copy of the following note by Mr. David R. Coker, of Harts Ville, South Carolina, on a proposed programme of farming in that State to meet cotton boll weevil conditions :—

The march of the boll weevil across the cotton belt has been accompanied by panic and demoralization. Farmers, bankers and merchants, frightened by one or two years of heavy losses, have, in

many cases, curtailed operations and credits to the points where farming was stifled and labour was forced to leave the country to prevent starvation. There are signs that a similar panic may occur in parts of this State unless means are taken to re-assure the people and point out a safe course for agricultural operations under boll weevil conditions. To this end a group of practical farmers and businessmen, in co-operation with the Extension Bureau, have studied the situation in the light of their own experience and that of other States and the accumulated experimental results of Governmental agencies, and beg leave to present the following suggestions and programme as one which will meet the situation, preventing demoralization and enabling our farming and business interests to continue profitable operations.

It is especially important to prevent our people from stampeding into new and untried fields of agriculture in which they will fail for lack of information and experience. Promising new crops should of course be tested and where proved successful should be increased as rapidly as the people gain experience but not faster.

The problem is not so much as to what to do as it is how to re-assure the people and get the information of how to proceed to every farmer, renter and share-cropper in the State. This must be done, if it is done at all, by the larger farmers, merchants, bankers and professional men who should make it their business to reach the isolated farmers and tenants and discuss with them the programme of operations under boll-weevil conditions. The greatest responsibility rests upon the landowners. If they are going to continue to own their lands, they will be obliged to see to it that those who farm them have correct information and closest supervision, for the average farm tenant must have sympathetic and correct instruction and active supervision until he thoroughly learns the new methods of operation.

A few broad principles of operation for the whole State may be suggested :—

First. Destroy immediately all cotton stalks as soon as the crop is gathered. This will prevent the hatching of millions of new

weevils during October. The old weevils do not hibernate until cold weather and the destruction of their food supply will cause them to die before frost. The carrying out of this suggestion at once is imperative and every effort should be made to induce every farmer in the State to do this work at once, for, if only a few do it, it will have little effect in reducing next year's weevil supply.

Second. During the fall and winter destroy all cover in which weevils may be hiding, burning ditch banks and margins of woods and cleaning up around stumps. Fodder and hay stacks should not be allowed to remain near cotton fields.

Third. Cotton should be liberally fertilized with a quick acting fertilizer containing about 50 lb. of available phosphoric acid per acre, ammonia and potash to be used according to the character and relative fertility of the soil. All applications of ammonia should be put down before the middle of June. Over-doses of potash have a tendency to delay maturity. Where the weed grows tall only a small amount of ammonia should be used as it always delays maturity and encourages overgrowth of stalk.

Fourth. Early planting of approved varieties of cotton with plenty of seed. The farmer should save at least three bushels of good seed for each acre he is going to plant. He should plant at least two bushels before April 1 in the lower half of the State and before April 10 in the upper half of the State, reserving a bushel per acre. If a stand is not secured by the first planting he should plant over not later than April 10 in the lower half or April 20 in the upper half. If large quantities of seed are used good stands are usually secured from extra early plantings and the experience is that under boll-weevil conditions the greatest crops are always made from the earliest plantings. If stands are not secured at a comparatively early stage, the land intended for cotton should be put into other crops.

Fifth. Cotton should be left thick in the drill. This distance should vary with the height of the natural growth of the plant, 3″ or 4″ not being too close as a minimum and 8″ or 10″ as a maximum.

Sixth. The question of poisoning for boll weevil is still in the experimental state but your Committee believes that poisoning with calcium arsenate is valuable, especially if done at the proper time and under favourable conditions. Heavy damage from plant lice following dusting with calcium arsenate early last August makes us doubtful as to this treatment when applied at that time. The weevils should also be picked from the plant in the early stages, and as soon as punctured squares are noticed they should be picked up twice per week until mid-summer. Rapid and thorough cultivation at all times should be employed and the crop should be gathered as fast as open to insure a high grade. In no case should more cotton be planted than can be properly handled at all stages and promptly picked by the labour on the farm, for it is the height of folly to plant a crop and let the boll weevil eat it up for lack of attention or allow it to become blue in the fields for lack of picking force.

The experience of many of our best farmers and numerous experiments conducted under the auspices of the Experiment Stations prove that it is absolutely essential in almost all sections to use around 300 lb. per acre of acid phosphate under cotton. In most cases if the amounts applied vary much, either above or below this standard, the crops were less profitable.

Everywhere it must be insisted on that the individual farmer and tenant raise an abundant supply of food and feed and that this food and feed be properly conserved. The man with a crib full of corn and hay, a smoke-house full of meat and molasses, a hundred bushels of sweet potatoes in a storage house and a garden full of vegetables cannot be put out of business by the boll weevil or any other pest.

Storage houses for keeping sweet potatoes should be everywhere constructed, as this is one of the greatest crops we have and one which every farmer can raise.

The note concludes with special suggestions for different tracts of South Carolina.

COTTON EXPERIMENTS IN MESOPOTAMIA.*

THE paper describes an experiment carried out with a variety or form of the American "Webber 49," called "Mesopot White." In spite of lack of irrigation, owing to disturbances in the country, 1,250 lb. of seed cotton per acre were obtained over the 80 acres used for the experiment. Other experiments giving promise were carried out with Egyptian cotton. There is now enough seed of Mesopot White available to plant 2,000 acres. The experiments have shown that the industry would provide full-time occupation for Arabs during the summer months; even with irregular treatment, yields equal to the average of Egypt can be obtained; the Arabs can be taught to cultivate cotton intensively as in Egypt; and that cotton growing on a large scale would provide for the prosperity of the country in general. [W. R. in *Jour. Text. Inst.*, 12th December, 1921.]

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CULTIVATION OF PIMA COTTON. †

FROM the results of field experiments it appears that thorough cross-pollination leads to an increased yield of seed and raw cotton. Bee-keeping near the cotton fields is advocated. [J. C. W. in *Jour. Text. Inst.*, 12th December, 1921.]

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* *Bull. Imp. Inst.*, XIX, pp. 227–229.
† Kearney, T. H. *Jour. Heredity*, XII, pp. 99–101.

PERSONAL NOTES, APPOINTMENTS AND TRANSFERS, MEETINGS AND CONFERENCES, ETC.

The post of Imperial Cotton Specialist in the Imperial Department of Agriculture is abolished with effect from the 9th August, 1921.

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Messrs. S. C. J. Bennett and H. Cooper have been appointed Second Bacteriologist and Pathologist, Imperial Bacteriological Laboratory, Muktesar, respectively.

***

Mr. G. F. Keatinge, C.I.E., I.C.S., Director of Agriculture, Bombay, has been permitted to retire from the Indian Civil Service from the 27th October, 1921.

***

Mr. Ganda Singh Cheema, Horticulturist to the Government of Bombay, was on privilege leave for 15 days from the 3rd February, 1922.

***

Mr. G. Evans, C.I.E., Director of Agriculture, Bengal, has been appointed to act as Director of Fisheries, Bengal, in addition to his own duties.

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Mr. Saadat Ullah Khan has been appointed Deputy Director of Agriculture, Madras.

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Mr. D. Ananda Rao, B.Sc., has been appointed Deputy Director of Agriculture, IV Circle, Madras.

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Mr. D. G. Munro has been appointed Assistant to the Principal, Professor of Agriculture and Superintendent of the Central Farm, Coimbatore, *vice* Mr. Ananda Rao, transferred.

MESSRS. ANGUS MCLEAN, ALEC. A. HENRY, H. T. ROBERTSON AND R. WATSON, who have been appointed to the Indian Agricultural Service, have been posted to Burma as Deputy Directors of Agriculture.

* * *

MR. D. QUINLAN, M.R.C.V.S., Director of the Civil Veterinary Department, Bihar and Orissa, has been granted an extension of furlough for two months.

* * *

MR. H. W. BLAKE, Agricultural Engineer, Bihar and Orissa, was on leave without pay from the 15th to 28th February, 1922.

* * *

MR. R. L. SETHI has been appointed Economic Botanist, United Provinces.

* * *

SARDAR DARSHAN SINGH, M.R.A.C., Deputy Director of Agriculture, Hansi (Punjab), has been granted privilege leave for five months, Maulvi Fateh-ud-din officiating.

* * *

MR. H. COPLEY, Agricultural Engineer, Central Provinces, on probation, has been confirmed in his appointment.

* * *

ON return from combined leave, Mr. F. J. Playmen, A.C.G.I., has been reposted as Agricultural Chemist, Central Provinces.

* * *

THE Twelfth Meeting of the Board of Agriculture in India was held at Pusa, under the presidency of Mr. S. Milligan, Agricultural Adviser to the Government of India, from the 13th to 18th February, 1922. There were eleven subjects on the agenda for discussion, and the meeting was attended by 80 members and visitors. A detailed account of the meeting, together with a photograph of the Board, will be issued in the next number of the Journal.

Review

Statistical Supplement to the Final Report of the Nitrogen Products Committee. (Published by H. M. Stationery Office, London, 1921.) Price 1*s.*

In this publication the data previously published have been revised and corrected in the light of the most authentic information which has become available since the publication of the final report.

The tables have, further, been brought up to date by the inclusion of figures for the year 1920.

The publication is of the greatest interest to agriculturists. A striking set of data are those relating to the world's resources in nitrogen products immediately preceding the war and at the present time.

We find that the total productive capacity from all sources has been doubled between the years 1912 and 1920, and amounts now to somewhat over 1·5 million metric tons of nitrogen per annum.

The main increases have been obtained from by-products ammonia (141,000 tons); cyanamide (302,000 tons), and synthetic ammonia (308,000 tons).

It is significant also that 43 per cent. of the world's supply is now derived from fixation processes.

Another aspect to which attention is directed, is the demand for nitrogenous fertilizers, the increased use of which, since the war, is noteworthy.

In the United Kingdom, for example, the average pre-war application of nitrogenous fertilizers amounted to 24,000 tons of nitrogen. In 1919 the actual quantity so used was 58,000 tons.

Similar increases have occurred in other countries. Further, it is estimated by competent authorities that the already very large total consumption of nitrogenous manures in the United States of America will be doubled within the next seven years.

To meet this anticipated demand, chemical research work on nitrogen fixation problems is being vigorously prosecuted both in Europe and in America.

To enable agriculturists to follow closely this race between supply and demand, it would be an undoubted boon if the publication under consideration could be periodically brought up to date to show how the world's nitrogen position is developing.

With regard to the relative merits of the different fixation processes and the prospects of the by-products and Chili industries little can be said, until more definite data concerning the Haber process and its modifications are available.

The present favourable position of German agriculture in the matter of nitrogenous manures deserves comment. The products of the fixation plants in Germany at present yield a large income to the State from direct taxation (amounting roughly to 100 per cent. of the cost price at the works). In spite of this tax the cost of nitrogenous manures in Germany is much lower than in England which has an open market.

These facts might, with advantage, claim the serious attention of the general public. [F. J. W.]

NEW BOOKS

ON AGRICULTURE AND ALLIED SUBJECTS

1. A HANDBOOK of Some South Indian Grasses, by Rai Bahadur K. Ranga Achariyar. Pp. VI+318. (Calcutta : Butterworth & Co. ; London : Constable & Co., Ltd.) Price, Rs. 4-8.
2. The Wheat Plant : A Monograph, by J. Percival. Pp. 473. Illustrated. (London : Duckworth.) Price, 63*s*.
3. More Hunting Wasps, by J. H. Fabre. Translated by Alexander Teixeira de Mattos. Pp. 376. (London : Hodder & Stoughton.) Price, 3*s*. 6*d*.
4. The Story of the Fields, by J. H. Fabre. Pp. 271. (London : Hodder & Stoughton.) Price, 8*s*. 6*d*.
5. Beet Sugar. Condensed description of its Manufacture, by F. Murke. Pp. 175. (New York : J. Wiley & Sons.) Price, 15*s*.
6. A Handy Book of Horticulture, by F. C. Hayes. Pp. 225. (London : J. Murray.) Price, 5*s*.
7. Dairy Farming on Arable Land : Five Prize Essays. Pp. 144. (Liverpool : R. Silcock & Sons.)
8. Management of Dairy Plants, by M. Mortensen. Pp. 358. (New York : The Macmillan Co.)
9. Text-book of Land Drainage, by J. A. Jeffery. Pp. 256. (New York : The Macmillan Co.) Price, 10*s*. 6*d*.

The following publications have been issued by the Imperial Department of Agriculture in India since our last issue :—

Reports.

1. Review of Agricultural Operations in India, 1920-21. Price R. 1-4.
2. Report of the Proceedings of the Fourth Entomological Meeting held at Pusa, 7th to 12th February, 1921. Price, Rs. 7-8-0.

PUBLICATIONS OF THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA

TO BE HAD FROM

THE OFFICE OF THE AGRICULTURAL ADVISER TO THE GOVERNMENT OF INDIA, PUSA, BIHAR,
and from the following Agents :—

(1) THACKER, SPINK & CO., CALCUTTA.
(2) W. NEWMAN & CO., CALCUTTA.
(3) RAI M. C. SARKAR BAHADUR & SONS, CALCUTTA.
(4) HIGGINBOTHAMS, LTD., MADRAS.
(5) THOMPSON & CO., MADRAS.
(6) D. B. TARAPOREVALA, SONS & CO., BOMBAY.
(7) THACKER & CO., LTD., BOMBAY.
(8) SUNDER PANDURANG, BOMBAY.
(9) RAI SAHIB M. GULAB SINGH & SONS, LAHORE.
(10) MANAGER, EDUCATIONAL BOOK DEPÔT, NAGPUR.

A complete list of the publications of the Imperial Department of Agriculture in India can be obtained on application from the Agricultural Adviser to the Government of India, Pusa, Bihar, or from any of the above-mentioned Agents.

These publications are :—

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